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STROMBOLI.

GEOLOGY

FOR

SCHOOLS AND STUDENTS:

OR,

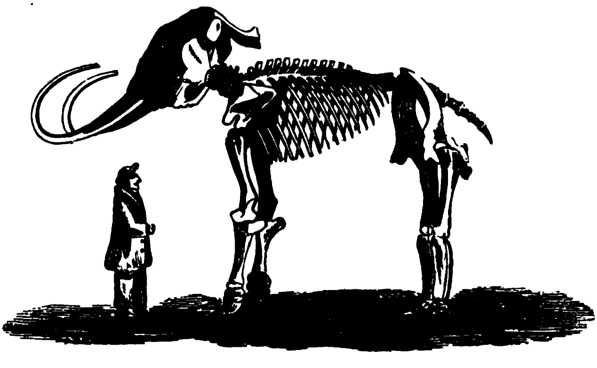
Former Worlds,

THEIR STRUCTURE, CONDITION, AND INHABITANTS.

BY

F. C. BAKEWELL,

AUTHOR OF
"ELECTRIC SCIENCE," "PHILOSOPHICAL CONVERSATIONS,"
"NATURAL EVIDENCE OF A FUTURE LIFE," ETC.



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PREFACE.

THE facts disclosed by researches in the strata that constitute the crust of the globe, and the insight they afford into the condition of the earth long antecedent to the creation of man, have rendered geology one of the most interesting branches of human knowledge.

Scarcely more than half a century has passed since attention was first directed to the various kinds of rocks that present themselves in different parts of the world, until which time nothing was known of the structure of the earth beneath the surface. The author's father, the late Mr. Robert Bakewell, was among the earliest of those who cultivated the science in England; and his "Introduction to Geology," published in 1814, was the first comprehensive work on the subject in this country. That work, in its progressive stages of development through five editions, formed the groundwork of knowledge to most of the eminent geologists of the present day, and it was for many years generally consulted as the best guide to the rocks and strata, and to the structure and condition of former worlds. Numerous intelligent and active investigators have since entered the field, and by their labours and their writings have greatly extended our acquaintance with the structure of the earth, and with the characters of its fossil organic remains. Only a few of those works, however, are adapted for the student of geological science; some of them having been written with a view to establish peculiar theories, others being limited in their scope to the examination of certain classes of rocks, and nearly all of them being published at prices which restrict their general circulation.

It has been the author's object in this work to give such a comprehensive and full description of former worlds, their structure, condition, and inhabitants, as will be sufficiently satisfactory to the general student; and, at the same time, form the foundation for future investigations to those who desire to enter farther into this highly interesting field of inquiry.

Since much of the interest that attaches to the study of geology is derived from speculations into the causes that have produced the various phenomena which an examination of rocks and strata discloses, the theories propounded to account for them have been stated, and the arguments by which they are supported have been considered. In treating this branch of the subject, however, it has been the author's endeavour to present the views of geologists, when they differ, in an impartial manner; and, by stating generally the arguments for and against proposed hypotheses, to allow the reader to judge whether or not the conclusions arrived at are sufficiently satisfactory.

Some variation from the usual classification of rock formations has been made, with a view to simplify the arrangement; and the nomenclature recently introduced by some geologists has been sparingly used, as extended investigations show that many of the terms are inappropriate, and tend to mystify or mislead.

Among the works principally consulted in writing the present volume, are—

Sir Charles Lyell's "Principles of Geology;"
——————— "Manual of Geology;"
Sir H. Delabeche's "Geological Observer;"
"Transactions and Proceedings of the Geological Society;"
"Reports of the British Association for the Advancement of Science;"
"Encyclopædia Britannica;" } Articles—"Mineralogy" and "Geology,"
"Encyclopædia Metropolitana;" } by Professor Phillips;
Dr Buckland's "Bridgewater Treatise;"
Dr. Mantell's "Wonders of Geology;"
Professor Owen's "British Fossil Mammals;"
Professor Ansted's "Geology;"
"Memoirs of the Geological Survey of Great Britain;"
Mr. R. Bakewell's "Introduction to Geology."

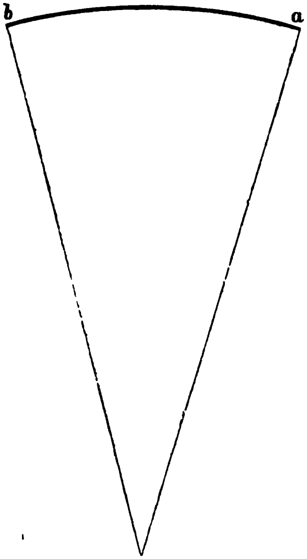
6, Haverstock Terrace, Hampstead.
May, 1854.

INTRODUCTION.

The term, Geology, is derived from two Greek words that signify a discourse or disquisition on the earth; a discourse, however, not confined to the external face of things. The science of Geology is specially directed to the investigation of the earth beneath its surface, as far down as human skill and intelligence have been enabled to penetrate. Though in some respects connected with physical geography —since both branches of knowledge relate to mountains and valleys, the diversities of land and water, the effects of climate, and the actions of rivers, torrents, and tempests—yet these features and phenomena, which constitute essential points in physical geography, are only incidental aids and illustrations in the investigations of the geological inquirer. Whilst the physical geographer examines the extent and heights of mountain ranges, the forests, seas, and water-courses, and the influence of soil and climate on the products of vegetation, and on animal life, the geologist strips the covering off the surface, explores the rocks below, examines their structure and relative ages, developes the proximate causes of the elevations of the land, opens the monuments of past ages of existence, and reveals the history of former worlds, inhabited by races of beings that have successively become extinct, but whose remains are entombed in the solid rocks, that serve to perpetuate for ever the knowledge that they once lived and flourished.

In these researches the geologist becomes the physical geographer of former worlds. He marks where seas and fresh-water lakes once covered the land, where rivers fertilized the soil, where extensive forests flourished, and he is enabled to trace the changes and influences of climate. The prints of footsteps, and the ripples of the water on the now indurated sand, serve to point out the shore left bare by the receding tide; and even the impressions of rain-drops are preserved to show that then, as now, the clouds showered down upon the earth.

These interesting revelations of the past history of the world, are found within a space which, compared with the diameter of the globe, is insignificantly small. The total depth of rock formations of which the geologist can obtain a survey does not exceed five miles, from the foundation of granite to the diluvial deposits on the surface. This limited sphere of observation extends little more than the two-thousandth part of the earth's diameter, and it is amply represented by the space occupied by the boundary line, *a*, *b*, of the arc of the circle in the accompanying diagram. When, therefore, we contemplate the mighty changes that have taken place on and beneath the surface, and when geologists speak of the upheaved mountains and receding oceans, a consideration of the small space in which such changes are effected will remove any doubts that may be entertained of the existence of powers within the mass of the globe capable to produce such effects on the comparatively thin covering of rocks that comprise the extent of man's cognizance.



The highly interesting facts and speculations developed by, and founded on, investigation into the structure of the earth, are not the only results from the cultivation of geology. It has also an eminently practical bearing. In the operations of mining, in agriculture, in the construction of railways, and other public works, in draining and in sinking for water, an acquaintance with the characters of the rocks beneath, and with the directions and positions of the strata, is of the greatest importance; and as the employments, the habits, and the social condition of a people are greatly influenced by the geological character of the country, it is essential to know the means of applying these resources to the best advantage.

GEOLOGY

For Schools and Students:

OR

FORMER WORLDS; THEIR STRUCTURE, CONDITION, AND INHABITANTS.

CHAPTER I.

SUCCESSION OF ROCK FORMATIONS.

Occurrence of different rocks in England: order of succession.—Stratification.—Elevation of the strata, and its effects.—Axis of elevation.—Unconformable stratification.—Dislocations of strata.—Different ages of rocks.—Organic remains: the application of them to determine the relative ages of strata.—Superposition of volcanic rocks.—Defective nomenclature of geology.—Tabular arrangement of rock formations.

WHEN we turn over the vegetable mould that covers the land to the depth, in some places, of a few inches and in others of a few feet, we arrive at a sub-soil of a different kind, which is generally harder than the earth above it. In the neighbourhood of London the sub-soil is found to consist of stiff clay, in Hertfordshire it is loose sand, in Wiltshire it is chalk, and farther to the west we find sandstone, limestone, and various kinds of slate. If the examination be made towards the north, we find nearly a similar series of rocks, but we should have to travel much farther to arrive at the sandstone and slate; and beyond them, in the northern part of Scotland, would be found granite.

After an extensive examination of this kind we should be able to determine the districts wherein these various sub-soils occur, and to point out the boundaries where the clay gives place to sand, the sand to chalk, and that again to the other rocks in succession. We should thus acquire a knowledge of the principal geological features of the island; but by this superficial kind of examination alone we should not attain any information respecting the real conformation of the underlying rocks, and we might be altogether in error regarding their relative positions.

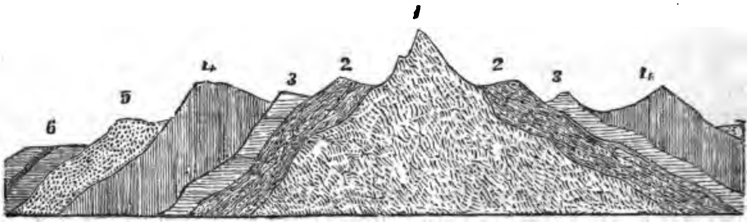
It might be supposed, for instance, that the different rocks met with have no traceable foundations, and that the clay, the chalk, and the sandstone extend to an indefinite depth, without having any relation in position to the adjoining rocks in the series. But if we extended our researches more deeply under the surface, we should in many places be able to penetrate through the sub-soil, and we should arrive at the next rock in the series within a much shorter space than if we were to walk along the surface of the land. In sinking deep wells in the neighbourhood of London, for example, at the depth of about 250 feet, the same kind of sands that are to be seen on the surface in Hertfordshire are found; and on sinking about fifty feet deeper, chalk like that of Wiltshire and Norfolk and Kent is met with. The thickness of the chalk bed under London is too great to be sunk through by ordinary means; but proceeding towards the west, after travelling some distance over the downs beyond Marlborough, a well might be sunk through the chalk, and then the same series of rocks would be found which appear on the surface in the neighbourhood of Bath.

By pursuing this course of investigation, and by examining the inclinations of the strata where they are exposed by precipitous elevations, or by railway cuttings, it would be ascertained that the different rocks in the series lie upon one another, and that they are brought successively to the surface by being inclined upwards. This important geological fact was known to miners long before geology was recognized as a science; experience having taught them that they should find certain successions of strata as they descended. It was from such experiences, confirmed by examination of the external characters of the country, that Werner, the German geologist, arrived at the conclusion that the different rock formations are deposited upon one another in a successive series; and this inference, from comparatively limited observation, has been since confirmed by the most satisfactory evidence.

To account for this succession of rocks resting upon one another, Werner supposed that all the materials of which they are composed were originally held in suspension by the waters of the ocean, and that the whole surface of the globe was submerged. The deposition of the suspended solid matters, it was imagined, took place in the order of their relative specific gravities, and thus formed successive strata, overlying each other like the leaves of a book; the subsequent gradual subsidence of the sea having left the dry land in its stratified condition. Though more extended observation has shown that this theory requires great modifications, yet the extensive agency of water in the formation of rocks is every where apparent; and in all parts of the world, with few exceptions, they preserve the same order of super-position.

The annexed section (fig. 2) exhibits the positions in which the principal rock formations would present themselves over a range of country from the mountains to the sea, when the strata have not been disturbed:

fig. 2.



In this section, 1 represents the rock called granite, which is considered to be the foundation whereon all the others rest; for it is never found lying upon any rock, in a stratified form. The next in the series are gneiss, mica slate, common slate, and limestone, all of which are crystalline. Then follow in succession sandstone, other limestones, the coal strata, chalk, sand, clays and diluvial depositions.

The preceding arrangement presents what is termed "conformable" stratification, in which the positions and directions of all the series conform to those of the rocks whereon they rest. A traveller passing over such a district, from the lowest stratum at 6 towards the granite, might assume, if he were not aware of the direction of the strata or knew the order in which the rocks he would meet with usually occur, that each one in succession rested on those he had passed, and on arriving at the granite he might infer that it was the uppermost rock of the whole series. It is evident, however, from the section, that such a conclusion would be directly contrary to the fact; for the granite, though the highest in the range, is the rock on which all the others rest.

Geologists generally agree in ascribing the cause of the lowest rock being thus brought to the top, to the uplifting of the granite, generally when in a state of fusion, by the action of some internal force. That granite and the rocks associated with it have once been in a melted state is proved by their crystalline structure, and by other more direct indications of igneous action; and it is supposed that they were forced upwards when in that condition. We shall enter more fully into the causes of this and of other geological phenomena when the phenomena themselves have been described; it is sufficient at present to notice that the general elevation of the strata is attributed to the agency of subterranean force; and admitting that cause to have operated, it satisfactorily accounts for finding the granite, which is the lowest rock, in the highest positions.

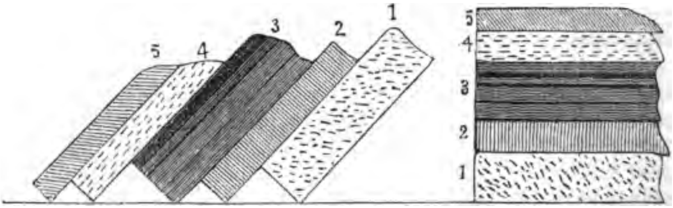
There can be little doubt that if a well were sunk through the clay near London sufficiently deep, it would cut through every stratum that is met with in travelling from London to Wales, but the thickness of many of the strata is so great that we should probably have to penetrate to a depth of ten miles before the granite was reached, and such a depth, or any approach to it, is altogether unattainable; for the deepest mine does not exceed 1000 yards. If, therefore, it had not been for the uplifting of the strata, we could have become acquainted with but very few of the rocks that constitute the crust of the globe. It is conjectured also, that there may be rocks lying beneath granite which a more violent internal action than any which the crust of the globe has yet experienced might bring to the surface.

In a continuous series of rock formations, when the strata on both sides of the centre of elevation can be observed, the inclination is seen to be in opposite directions, as shown in the preceding section, where on one side the strata incline upwards to the left, and on the other side towards the right. A traveller passing over such a country, would, after crossing the granite, come to the same kind of rocks he had before seen; but they would then be in the reversed order, and inclined in opposite directions.

The technical name given to such a centre of elevation is the "anticlinal axis;" and it is an important consideration in taking a geological survey of a country to ascertain the direction of such lines of elevation, as they determine the inclination of the strata.

It is customary to adduce, as a familiar illustration of the positions of stratified rocks, the overlying leaves of a book, when placed horizontally or inclined; but a much better notion of the positions and elevations of strata may be gained by placing upon one another several boards, variously painted and of various thicknesses. If four or five such boards, about nine inches long and six inches wide, be laid upon one another on the table, they will represent the undisturbed strata disposed horizontally, of which only the uppermost can be seen by passing over the horizontal surface. If the lowest board be then raised at one end, the upper ones will slide down and the edge of the lowest board will be exposed to view at the top, as represented in the diagram.

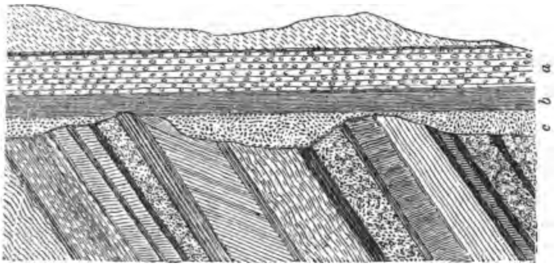
fig. 3.



In this illustration, the board marked 5 may represent the clay near the surface, 4 the chalk, 3 the coal strata, 2 the slate formations, and 1 the granite.

If all the rock formations presented themselves in the same order and with the regularity shown in the diagram, the study of geology would be very easy. All the student would have to do would be to acquire a knowledge of the appearance and structure of each, and the order in which they occur; and he would be able, under any circumstances, to ascertain his exact geological position, and the succession and inclination of the strata observed in any direction around him. But though a general correspondence is maintained in the character and succession of rocks in all parts of the world, so that when the same kinds of strata are found their relative positions in the general arrangement may be predicted, yet in some countries whole classes of rocks are missing, and in others, rocks of different kinds are interposed. Neither must it be imagined, that the strata are generally inclined to one another in the same directions as represented in the diagram. So far is that from being the case, that it is most usual to find all the strata above the coal, lying in what is termed an "unconformable" position, as shown in fig. 4, where *a b c* represent comparatively horizontal beds of sand, chalk, and clay resting upon the more vertical beds containing seams of coal. It may be readily inferred from such an arrangement of the superincumbent strata, that they were deposited in those positions after the rocks whereon they rest had been lifted up; and that the overlying beds were consequently of subsequent formation.

fig. 4.



The conformable and unconformable stratification already noticed, may be considered as the positions in which the rocks were originally deposited, or which they have assumed by the impulse of forces acting simultaneously upon all. But agencies of more confined extent have very frequently disturbed and contorted the original positions. Eruptions of igneous matter have covered the tops of the loftiest mountains, and have dislocated or removed the solid strata; the mechanical action of water has swept away entire beds of rocks; deposits of rivers and of former lakes have superposed local formations, distinct from the general system of stratification; and volcanoes and earthquakes have added to the disturbing causes which have disarranged the original conformations. These disturbances have created difficulties in the pursuit of geological investigations, and have afforded abundant scope for speculation to ingenious theorists.

On viewing the structure and positions of the rocks that compose the general order of stratification, some marked distinctions are observable, which induced geologists, in the earlier stages of the science, to class them into three divisions of primary or primitive, secondary and tertiary formations. These divisions were founded on the supposed chronological order of their creation. The granite and other crystalline rocks associated with it, do not bear the marks of having been deposited from aqueous solution; hence they were considered to be the first rock formations, and obtained the name of primary. The stratified rocks resting upon them, including the chalk, were called the secondary formations; and the upper sands, clays, and diluvial deposits received the name of tertiary. A subsequent distinction was made by dividing the secondary formation—the lower portion, resting on the crystalline rocks, being called the transitive series; and the tertiary strata were also subdivided into tertiary and diluvial.

The opinions of geologists, regarding the relative ages of the rocks, were founded on examination of their structure, as well as on the order of their succession. Imbedded in the various strata were found the fossilized remains of plants and animals entirely distinct from any that now exist. These relics of a former world comprise fossil plants, shells, fishes, reptiles, birds, and quadrupeds; some of which are of monstrous size, and most of them unlike any living species. On further investigation, it was ascertained that successive formations of strata contain their peculiar organic remains. Those in the lower rocks consist entirely of organized creations of the more simple kinds; as the order of succession proceeds towards the surface, and is consequently more recent in date, plants and animals of more complicated organizations are imbedded; and in the tertiary and diluvial strata, the remains of quadrupeds that suckled their young are discovered; and those of shell-fish and reptiles closely allied to, and in some instances identical with, existing species.

This progressive order of organization, commencing with the simplest and proceeding to the more complex development, as the strata approach more and more near to the surface, strongly supported the opinion of the progressive ages of the strata. As granite and its accompanying crystalline rocks present no traces of organic remains, they were assumed to have been formed before the world was fitted for the development of organized life; and the name of primary seemed to be peculiarly fitted to that class of rocks. A few widely-scattered remains in the upper slates and in the lower series of sandstone and limestone, induced the belief, that at the period of their formation, the world was passing into a state calculated for the support of living beings; therefore the term "transition," was considered an appropriate designation. When we ascend to the coal formation, we perceive evidence of the most profuse vegetation; forests, trees, pines, and ferns having then flourished in sufficient abundance to form the beds of coal that now serve us for fuel. In the secondary formation are seen the fossil bones of aquatic creatures of prodigious size; and in the uppermost of the tertiary beds are found the remains of the mammoth, the mastodon, and the megatherium, that have only just passed away from the world, to give place to man and the tribes of animals that are under his command.

Though the examination of the fossilized organic remains in the successive depositions of rocks confirmed the opinion of the progressive order of their creation, and thus sanctioned the adoption of a chronological nomenclature, it became evident that the division into four or five formations was altogether inadequate to express the number of distinct depositions on the primary rocks; and modern geologists have been inclined to reject the classification by chronological order, especially since the discovery, in some rare instances, of granite resting upon comparatively recent rocks.

The discovery of fossils, and their association with peculiar series of strata, have thrown a new light on geological researches, by the means thus afforded of connecting one kind of rock with another in point of time, and of distinguishing two specimens of similar structure and appearance, by the different characters of their organic remains. The presence of organic remains also serves to determine in a decisive manner the character of the rocks in which they appear, and to disclose the recurrence of geological epochs that would otherwise have been unknown. Sometimes a stratum containing marine shells is found resting on beds impressed with remains of the stems and leaves of plants; and these alternations of marine and land deposits are occasionally repeated several times on ascending a mountain-range. Hence the geologist infers that the lofty eminence whereon he stands was at one time submerged beneath the ocean; that after a series of years it became dry land; that it was again submerged, and was once more lifted above the water.

The organic remains which thus give distinctive characters to rocks, and reveal the epochs of their formation, are abundantly diffused, and sometimes even constitute the entire mass of elevated mountains. The magnitude of these depositions shows that they must have required long periods of time for their accumulation; and though no estimate can be made of the actual duration of these geological periods, yet such evidence as the alternating thick beds of organic remains afford, proves that countless ages must have elapsed between the formation of the crystalline rocks that rest immediately on the granite, and the deposition of the upper series of the tertiary strata.

We have hitherto noticed only the arrangement of rocks as they appear in successive series, either resting conformably on each other, or deposited after the underlying strata have been elevated. In addition to these, however, there are igneous rocks that have been protruded through the crust of the globe at comparatively recent periods, and which rest on the uppermost of the general strata. These igneous rocks, the principal of which is basalt, are found in some places crowning the highest mountains; elsewhere they rise from the sea and from lofty precipices, of which the Giant's Causeway, on the northern coast of Ireland, is a well known instance.

The regularly stratified rocks have been frequently dislocated by this protrusion of the molten basalt; and in the coal districts especially, the basaltic "dikes," as they are called, have forced themselves through the superincumbent strata, which they have upheaved and distorted to a great extent.

No organic remains have been found in basalt, which resembles, in its component parts, some of the primary rocks that are associated with granite. From the circumstance that it is sometimes protruded through granite, it seems not improbable that basalt forms the foundation on which granite rests; and though one of the most recent geological formations, it may be the oldest rock exposed on the surface of the earth.

In the classification and nomenclature of the series of formations and strata, no generally approved system has yet been adopted. Though the original chronological order has been objected to, yet most English geologists retain the terms primary, secondary, and tertiary, as indicative of three principal geological epochs. These have been subdivided into separate formations, some of which are named from the localities in which the strata are well developed, or from the prominent rock of which they are composed. It is to be wished that some consistent and intelligible system of nomenclature was established, as the study of geology is greatly impeded by varieties of senseless names that impart no idea of the character of the rocks; and frequently fanciful, if not erroneous, views are disguised by terms derived from the Greek, and become accepted as authorised designations, without sufficient examination of their propriety. "It is greatly to be regretted that a morbid desire to obtain celebrity, by inventing new nomenclatures, should so much prevail among the cultivators of natural science. The author is of opinion, that a more simple arrangement of rocks might be made without any material change of the present names; and he is persuaded that such an arrangement will take place in a more advanced state of the science."* In the meantime, we must endeavour to make the best of the orders of arrangement and nomenclatures that are at present most generally received. In the following tabular arrangement, in a descending series from the surface, many names will be found that have either no sufficient meaning, or tend to mislead and to mystify. They have been adopted in this instance in accordance with the practice in recent geological works; but we shall only employ them when it is necessary to indicate to the geological student the names given to certain formations or series of strata in other publications that he may consult.

It must be borne in mind, that the thickness of the different strata refers to the points of their greatest development, and that in no part of Great Britain are all the successive strata to be found, and some of them are of very limited extent:

ORDER OF SUCCESSION OF THE DIFFERENT GROUPS OF STRATA.

TERTIARY FORMATIONS.

Recent Nomenclature.		*Character and Thickness.*
Pleistocene, or Newer Pliocene.	Alluvium. Diluvium.	Superficial deposits, marine, and freshwater, covering stratified rocks; remains of quadrupeds, many of extinct species.
	UPPER TERTIARY.	
Pliocene.	Norwich crag.	Abundance of fossils of recent and existing species, including large mammalian quadrupeds. Thickness, 30 feet.
	MIDDLE TERTIARY.	
Miocene.	Red crag. Coralline crag.	Marine fossils, comprising several existing species. 40 feet.
	LOWER TERTIARY.	
Eocene.	London clay. Sand. Plastic clay.	Stiff clays, alternating with sands and gravel; fossils of tropical plants, mollusca, and fishes. 600 feet.

SECONDARY STRATA.

	UPPER SECONDARY.	
Cretaceous system.	Chalk with flints. Chalk without flints. Upper green sand. Gault. Lower green sand.	Fossils of zoophytes, mollusca, sponges, fishes, ammonites, echinites. Thickness, 1300 feet.
Wealden group.	Weald clay. Hastings sand. Purbeck sand.	A local group of freshwater strata; fossils of plants, fruits, freshwater shells, and gigantic reptiles.

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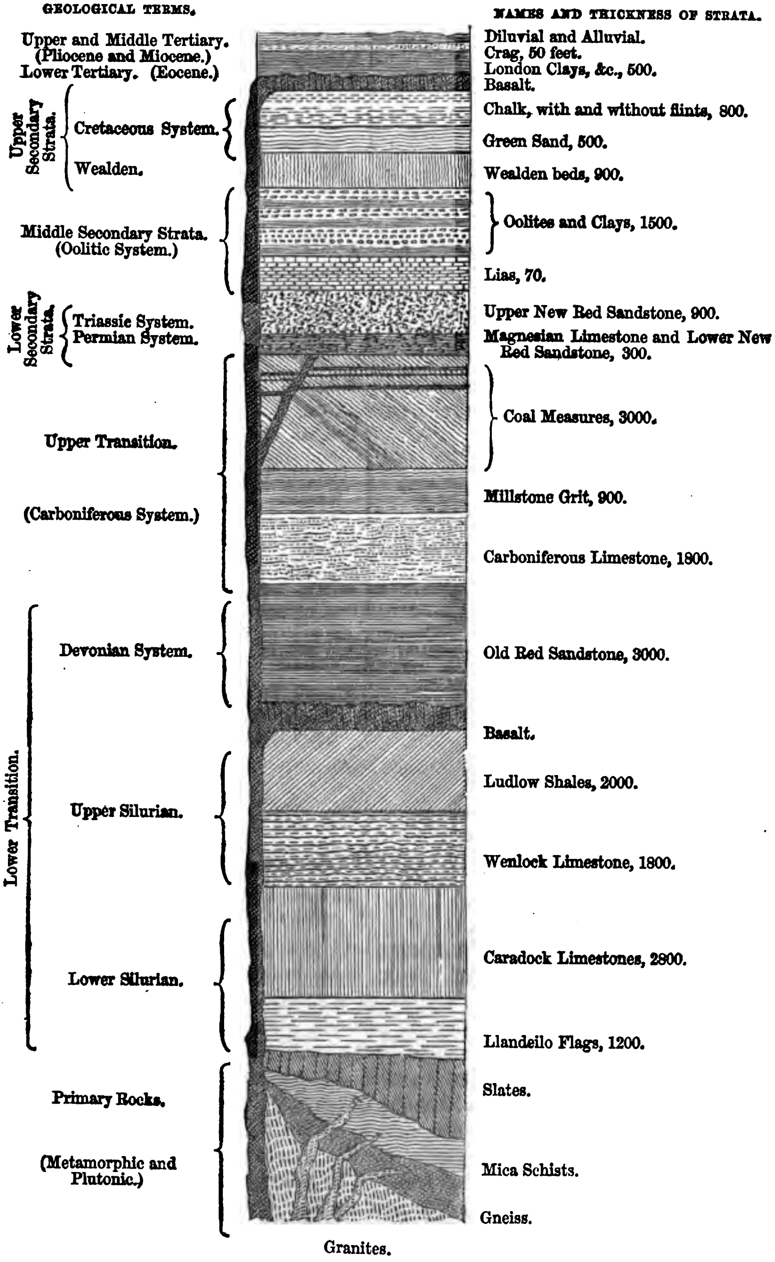
* Introduction to Geology, by Robert Bakewell, fifth edition.

MIDDLE SECONDARY.

Recent Nomenclature.		*Character and Thickness.*
Oolitic system.	Portland stone. Portland sand. Kimmeridge clay. Coral rag. Oxford clay. Cornbrash. Forest marble. Bath oolite. Inferior oolite. Calcareous sand. Lias limestone.	Limestones, clays, and sands of different structures; the limestones being generally studded with egg-shaped particles; numerous fossils of gigantic marine reptiles. Thickness, 2500 feet.
	LOWER SECONDARY.	
Triassic system.	Red marl. Upper new red sandstone and muschelkalk.	Sandstone, red and coarse; limestone combined with magnesia, sometimes hard and crystalline; fossils rare, but footprints of reptiles in the sands. Thickness, 1200 feet.
Permian system.	Magnesian limestone. Lower new red sandstone.	
	TRANSITION ROCKS.	
	UPPER TRANSITION.	
Carboniferous system.	Upper coal grits. Coal measures. Carboniferous limestone. Carboniferous shales.	Profuse distribution of carbon in lime and coal; metalliferous; abundant vegetable remains, and scarcity of other fossils. Thickness from 1000 to 6000 feet.
	LOWER TRANSITION.	
Devonian system.	Old red sandstone.	Siliceous particles mixed with coarse slate or limestone; fossils rare. Thickness, 3000 feet.
Upper Silurian system.	Ludlow shales. Dudley limestone. Dudley shale.	Marine formation; abundantly fossiliferous. Thickness, 3800 feet.
Lower Silurian system.	Caradoc sandstones. Llandeilo flags.	Stratified; containing numerous marine fossils of low organization. Thickness, 3700 feet,
	PRIMARY ROCKS.	
Metamorphic.	Slates. Crystalline limestones. Hornblende schist. Mica slate. Gneiss.	Crystalline, not stratified; no organic remains; very metalliferous. Thickness not determined; supposed to exceed two miles.
Plutonic.	Granite.	Mingled crystals of felspar, quartz, and mica; the lowest rock known.

In the preceding tabular arrangement many of the minor strata are omitted; nor have the volcanic rocks been included, as they are unconnected with the progressive orders of stratification. They have been ejected from beneath at different periods, some comparatively recent, and either lie upon the stratified rocks, or are protruded through them in thick veins. These rocks consist of basalt, porphyry, and their varieties, in which the constituents of granite are blended in various proportions and altered by the action of heat. The thickness of the basaltic covering on some parts of the Andes in South America is estimated at fourteen thousand feet. The accompanying diagram, which represents the principal rock formations and their relative thicknesses, with the eruptions of volcanic rocks introduced, will serve to show the order of succession still more clearly.

DIAGRAM OF ROCKS AND STRATA.



The geological student must not be discouraged by the array of strange names that he observes in the list of rocks and systems that comprise the geological series. There is much valuable and interesting knowledge to be gained without studying the classifications and systems, which have been formed without distinct guiding lines, and which are frequently altered to conform to the opinions of speculative geologists. The want of a scientific and intelligible nomenclature becomes more strongly apparent when the names that have been given to rocks and systems are thus presented at one view. It might seem, from the terms applied to several of the groups of strata, that they are peculiar to certain districts; but when it is known that rocks of the same character, and classed in the same system, are to be found in most parts of the world, the application of local names to generally distributed rocks seems strangely inappropriate. There is a still more remarkable inaptitude of terms to be observed. It may be thought sufficiently misleading to nominally limit extensive groups of strata to the confines of Devonshire, Wales, or Cumberland, disguised and mystified as Devonian, Cambrian, and Cumbrian systems; but when, in addition to local limitation, there are selected for the designation of systems of rock formations the names of people and kingdoms long since extinct and unknown, the absurdity of such a nomenclature appears to arrive at its climax.

CHAPTER II.

THE CONSTITUENTS AND CHARACTERS OF ROCKS.

Elementary substances of rocks: silica, alumina, lime, magnesia, alkalies, carbon, sulphur, iron, manganese.—Compound materials of rocks: quartz, felspar, mica, talc, chlorite, slate, hornblende; their chemical compositions and characteristic differences.—Calcareous rocks; marble, chalk, and gypsum: their peculiarities.

THE component parts of rocks are very few, and many that have different names and present different appearances are composed of the same elementary substances, either in other proportions or differently arranged by the circumstances of their formation. There is not in mineralogical, as there is in chemical combinations, any definite proportions in which the elementary substances unite; and the proportions being indeterminate and the circumstances of formation being frequently very different, there appears to be almost an infinity of compounds contrasted with the very rarely occurring simple rocks. The general absence of uniformity of structure, and the various modes in which the materials are combined, occasion considerable difficulty in distinguishing two or more assimilated rocks from each other, the gradations in which they blend together being sometimes almost imperceptible.

The four earths—silex, alumina, lime, and magnesia—constitute about nineteen parts out of twenty of all the known rocks. They are mostly combined with potass, soda, carbon, sulphur, iron, or manganese in minor proportions. The metals, which are found in veins intersecting strata and beds, are not considered as constituent parts of rocks, and they form a very inconsiderable part of the crust of the earth.

Silex, or silica, is often found nearly pure, but seldom in very large masses. Rock crystal is an example of silex in its purest form. Quartz, flint, and sand, are also composed of silex, with a small admixture of earthy matter. This mineral is extremely hard, will scratch glass, and gives great hardness to all the rocks with which it is combined. The point of a knife makes no impression on it. Silex, when pure, can only be fused by the oxyhydrogen blowpipe; but when mixed with lime, it may be fused at a much lower heat. It is nearly insoluble in pure water. Fluoric acid dissolves silex, and alkaline solutions also take up a portion of it. The specific gravity is 2·66. Silex is combined so largely with most rocks that it is supposed to constitute about one-half of the whole. Those which contain large proportions of silex are termed silicious. This earth is not a simple body; it was decomposed by Sir Humphry Davy, and was found to consist of a peculiar basis, called silicium, and oxygen, in the proportions of 49 of the base to 51 of oxygen.

Alumina is also a decomposable earth. It is found in the greatest purity in the sapphire and the ruby, which consist almost entirely of this earth; but in its ordinary state, it constitutes the plastic principle of clays and loams, and was formerly called argil, from the French, and argillaceous earth. Alum contains it in great purity, combined with sulphuric acid and water, and from that salt it derives its present chemical name. Alumina is extremely unctuous to the touch, and absorbs thirty per cent. of water. It is even more infusible than silex. All the rocks with which it is ordinarily combined possess more or less of its plastic properties, and are termed argillaceous. The colouring matter of clays is iron, for which alumina has a strong affinity. Specific gravity, 2·0.

Lime consists of a metallic base, called calcium, combined with oxygen, like the other earths. It possesses so strong an attraction for water and for acids that it rapidly absorbs carbonic acid and water from the atmosphere. In the state in which it is generally found, it is combined with nearly one-half its weight of carbonic acid. In that condition it constitutes marble, chalk, and mountain limestone. When deprived of water and carbonic acid it forms quick-lime, and is then very caustic. Lime requires intense heat for its fusion, and is not soluble in less than 500 parts of water. Specific gravity, 2·3. Rocks combined with lime are called calcareous. The carbonic acid is liberated by all other acids and produces effervescence, which affords a ready test of the presence of carbonate of lime.

Magnesia is also the oxide of a peculiar metal. The earth is known as a fine powder, of the specific gravity 2·3. It is insoluble in water, but is soluble in acids, with which it forms crystallized salts. It is seldom found alone, but when combined with limestone it forms extensive beds of rock.

The alkalies, potass and soda, and muriatic and phosphoric acids, form constituent portions of some rocks, though to a very limited extent.

Potass is principally seen combined with silex and alumina in felspar, which is a chief ingredient in granite; and this alkali tends, by its attraction of moisture from the air, to facilitate the decomposition of the rocks with which it is combined.

Soda is chiefly important by its forming, in combination with muriatic acid, common salt, and thus communicating, from some unknown source, saltness to sea water. Phosphoric acid, combined with lime, produces the substance of which the bones of animals are composed. It possesses great value as manure, and is occasionally met with in large masses.

Carbon is abundantly diffused through the Transition and Secondary formations, either combined with limestone in carbonic acid, or in solid masses among the coal measures, or entering directly into the composition of slates. It thus forms an important constituent of the mineral as well as of the vegetable and animal kingdoms. It is one of the few non-metallic substances that chemists have not yet decomposed, and when in its purest state, black charcoal is capable of being crystallized into the splendent diamond.

Sulphur is another elementary substance that forms an ingredient of rocks, though chiefly confined to volcanic districts. When combined with oxygen, however, as sulphuric acid, it unites with lime, and constitutes beds of gypsum or alabaster.

Iron enters into the composition of many rocks. It has a strong affinity for oxygen, and combines with it in four proportions; the most important of which are the black and the red oxides, the latter containing more oxygen than the former. It is the red oxide, or iron rust, that gives colour to clays and gravel, and most of the rocks with which iron is associated. The specific gravity of the metal is 7·7, which is more than three-times that of the earths; consequently, when iron forms an appreciable portion of a rock, it is of a greater specific gravity than the earths. Rocks combined with iron in a black oxide are liable to decomposition, owing to the absorption of a further portion of oxygen from the atmosphere to convert the metal into a red oxide, and by this process the rock is rusted. The pigment called red ochre is an oxide of iron, and occurs in veins in primary rocks.

Manganese forms so trifling a portion of rocks as scarcely to deserve notice among their constituent ingredients. It readily oxidizes, and falls into a black powder, which imparts a dark red colour with the associated earths. Specific gravity, 8·0.

It will be observed that the component parts of all the geological formations consist principally of materials that are compounds of oxygen with various metallic bodies; and that iron, manganese, carbon, and sulphur, are the only elementary substances which enter directly, and comparatively sparingly, into their compositions. In every rock, from granite to the Norfolk crag, oxygen forms the chief feature, and thus we may perceive that that most active agent of nature, which vivifies, stimulates, and destroys the existing orders of beings, was also exerting its energies in former worlds at the earliest dawn of creation.

The substances noticed as those that constitute the materials of all rocks enter into several antecedent combinations, which serve as proximate elements in the constitution of those of more compound structure. The primary rocks, for instance, are formed by the blending together of quartz, felspar, mica, hornblende, and talc, each of which is composed, almost entirely, of different combinations of silex and alumina. It will be necessary, therefore, to give a short description of the characters of the antecedent compounds which constitute the materials of granite and the other primary rocks.

Quartz is the name given to the forms in which silica generally appears, mixed with a small portion of alumina. When perfectly crystallized and colourless, it is called rock crystal; the most common shapes of which are six-sided prisms capped with six-sided pyramids. Some very fine specimens of this kind are to be seen in the mineralogical department of the British Museum. Many gems are composed of quartz, combined with iron or other earths, from which they derive their colour. Topaz, amethysts, carnelian, agates, tourmalin, are composed almost entirely of quartz, and in its colourless state of rock crystal it constitutes "Irish diamonds," which approach in hardness the real gem. As generally found in rocks, quartz is in a semi-crystalline state, more or less translucent, and has, when it is broken, a splintery fracture, and a greasy appearance. It can be fused alone only by intense heat; but by the addition of an alkali, it may be melted at a comparatively low temperature, and forms glass. When quartz occurs in large masses it is generally of a white colour, and in that state it is associated with gold in the "nuggets" of Australia and California.

Quartz, when not combined with other rocks, is generally in a granulated condition. The wearing down of the rocks containing quartz by the actions of water and of the atmosphere, has formed the beds of sandstone and sand that are accumulated in thick strata among all but the primary rock formations, and which at the present day cover the sea shore.

Felspar is a very abundant rock, and enters largely into the composition of granite. It consists principally of silica, combined with alumina and potass, in the proportions of about 62, 17, and 13 respectively, though different specimens vary considerably in their relative quantities. Its cleavage is generally more splendent than that of quartz, but it is not so translucent, nor is it found perfectly transparent. The crystals of felspar vary with its constituent parts, but the general character is rhomboidal. The presence of a large portion of potass is a marked chemical characteristic of felspar contrasted with quartz, and renders it fusible into a hard kind of glass without the addition of more alkali. The potass, which usually constitutes one-seventh part of felspar, facilitates its decomposition, and the disintegrated rock produces, by the liberation of alumina and silica, the finest kind of porcelain clay.

There are several varieties of felspar, the colours varying from white to red in every shade. The analyses of these different specimens gave the following results:

Silica	62·83	66·75	60·25
Alumina	17·02	17·50	22·00
Lime	3·00	1·25	0·75
Potass	13·00	12·00	14·00
Oxide of Iron	1·00	0·75	1·00
	96·85	98·25	98·00

There is a felspar called compact felspar, which is harder and much less fusible than the common kind. The difference arises from its containing a smaller quantity of alkali and more lime; and the proportion of alumina to silica is greater. The crystals in porphyry are usually compact felspar.

Mica forms another constituent of granite. Its name, derived from the Latin, indicates its shining or glistening character. Its structure is finely laminated, therefore it may be divided into very thin sheets, which are colourless, transparent, and highly elastic. Mica and compact felspar afford an illustration, in the mineral kingdom, of the aggregation of nearly the same elementary parts into very different forms. In chemical composition there is little difference, with the exception of a larger proportion of oxide of iron in mica; yet one is a rigid and opaque mass, the other soft, elastic, beautifully transparent and glistening, and is easily separated into the thinnest imaginable flakes. Both minerals melt into the same kind of glass or enamel.

Talc is a mineral that resembles mica in its laminated structure and transparency, though when in a mass it has a green colour. The principal characteristic differences between talc and mica are, that talc is not elastic, therefore when bent does not regain its form, and it also feels soapy on the surface. The comparison of talc and mica presents an illustration of an opposite kind to that of mica and felspar, for their external characters are similar, whilst their chemical constituents are not alike. There is only a very small quantity of alumina in talc, and a large proportion of magnesia.

Chlorite closely approximates to talc, and sometimes blends with it in undistinguishable gradations. It derives its name from its green colour, and not, as might be supposed, from its containing chlorine; the mere incident of colour having, it is to be regretted, been considered by the mineralogist and the chemist sufficiently characteristic to give the same distinguishing name to things entirely different. The chemical constituents of chlorite are nearly the same as those of talc, with a smaller proportion of silica, and more magnesia and oxide of iron. Its structure is minutely foliated, and its fracture presents a glistening lustre. Neither mica, talc, nor chlorite, occur separately in mountain masses, but they often form component parts of rocks. In the granite of the Alps, near Mont Blanc, talc generally supplies the place of mica.

In all ranges of primary and transition rocks, slate occupies an important position. Its laminated structure, which facilitates its cleavage into thin slabs for roofing houses, is well known. In some slates, the lamination is more massive, and it may be split into slabs several yards long, and two or three inches thick, whilst others are so splintery as to be useless. The laminated structure is probably owing to a semi-crystallization, which has disposed the slate to cleave in parallel planes; but in some instances where this laminated structure is observed, it is evidently owing to the effects of stratification, one thin layer having been deposited over another. Some of these "schists," as they are called, have acquired this form of structure by the interposition of very thin layers of mica. The slates from the Wicklow mountains are beautifully variegated, and though they do not bear the polish of marble, they are scarcely less beautiful. They are cut into thick slabs, and are formed into mantelpieces, tables, and other useful articles. In the constituents of slate, as of most of the primary and lower transition rocks, silica and alumina form the principal portions. Its specific gravity is 2·7.

Hornblende frequently occurs as an ingredient of primary rocks. Its colour is greenish black, with a subdued shining lustre, and compact fracture; and when breathed upon it emits a peculiar smell. It is not so hard as felspar, but it is more difficult to be broken, owing to its not being so highly crystalline. Its marked characteristic difference from felspar consists in its containing less alumina, and a very large proportion of oxide of iron—nearly thirty per cent. Its specific gravity exceeds that of felspar, in the proportion of 3·25 to 2·57.

Hornblende is sometimes found in mountain masses, though it most frequently occurs in combination with other minerals, and when minutely disseminated through them, it forms the class of rocks that are called "trap." These rocks, with which basalt is associated, are supposed to be of igneous origin, or to have been erupted through the surface by the agency of heat, after the deposition of the other rock formations.

In Cornwall, and in the Isle of Mona, in Anglesea, there are masses of a beautiful rock, called "serpentine," from its variegated green colours, which closely approaches hornblende in its constituent parts, with the addition of chlorite.

In the preceding elementary rocks, silica and alumina, either combined or separately, form the bases; and the other ingredients are generally the same in different proportions, and differently arranged, so as to give sufficiently marked distinctive characters to each. The following tabular arrangement of their constituent parts presents at one view the points of correspondence, and of difference in their chemical combinations. It must be borne in mind, however, that the analysis of specimens of each rock gives only an approximation to the general constituent parts; for rocks classed under the same name, and in essential respects similar, as frequently differ in their chemical compositions as they do in their colours. As such great differences exist in their general characters, it is unnecessary to give the decimal parts of separate analyses.

	Quartz.	Felspar.	Mica.	Talc.	Chlorite.	Slate.	Hornblende.
Silica	98	67	47	62	50	49	42
Alumina	2	18	22	2	26	24	12
Magnesia	0	0	0	27	0	2	3
Lime	0	2	0	0	2	0	11
Potass	0	12	14	0	17	5	0
Oxide of Iron	0	1	15	3	5	11	30
Oxide of Manganese	0	0	2	0	0	1	1
Carbon	0	0	0	0	0	1	0
Water	0	0	0	6	0	7	1
	100	100	100	100	100	100	100

In the preceding table it will be observed, that lime forms generally but a very small proportion of any rock, and that in most it is altogether absent; but there is a class of rocks of which it constitutes the base, almost as prominently as silica does in those already noticed.

Most of the rocks into which lime enters as a principal ingredient, are remarkable for the similarity of their constituent proportions, though their structure varies even more than those of felspar and mica. A hard, highly polished, and beautifully coloured marble, presents no features in common with a piece of soft, white, coarse-looking chalk; yet their chemical constituents may be exactly alike. The proportions of 57 parts of lime and 43 of carbonic acid, are those in which carboniferous limestones generally agree; but, in some instances, not only is the stone hard, and difficult to be broken, but the whole mass is composed of fossilized shells; and in other places we find the same component parts arranged in the form of transparent crystals. There are points, however, in which all limestones coincide: the hardest may be scratched with a knife, and they all effervesce when a drop of acid is applied. Carboniferous or mountain limestone occurs over wide-spread districts, and is to be considered rather as a distinct formation than as a constituent part of other rocks. Though its chemical composition agrees exactly with that of chalk, the structure and appearance, and the geological positions of limestone and chalk differ so much, that they are regarded as belonging to separate formations.

Magnesian limestone, called dolomite, occurs in beds of considerable thickness and of great extent in the north of England, resting on the Newcastle coal measures, and it forms the leading feature in the "Permian system" of geological arrangements; that name having been given to it because it is well developed in that part of Russia occupied by the government of Permia. Its constituents are, lime 30, magnesia 20, carbonic acid 47, with small portions of alumina and iron. Magnesian limestone effervesces only feebly when acids are applied. Its specific gravity, 2·8, exceeds the average of other rocks.

Gypsum is another variety of limestone, which sometimes is found in thick beds, occupying considerable areas. It varies much in its structure and appearance. Its finest white variety is called alabaster. When more distinctly crystallized, it forms selenite, a remarkably fine specimen of which has been presented by Prince Albert to the British Museum. Its constituents are, lime combined with sulphuric acid in the proportions of 32 lime, 30 sulphuric acid, and 38 water. When burnt to expel the water, it forms plaster of Paris, which absorbs moisture rapidly, and becomes again solidified, but with a different structure.

The descriptions we have given of the elementary mineral substances that enter into the composition of the more compound rocks, to be subsequently noticed, will serve to give the geological student an idea of their general characters and structures; but it will be impossible to obtain a knowledge of them in their various grades of change without an examination of specimens.

CHAPTER III.

PRIMARY ROCKS.

Classification of primary and transition rocks.—Granite the oldest known rock: its composition and structure.—Variations in granite.—Granite of Mont Blanc.—Occasional inversions of the order of superposition.—Granite an igneous rock.—Granite veins.—The term primary as applied to granite rocks.—Granite of different ages.—The granite of Glen Tilt; junction of it with limestone.—Gneiss and mica slate: their relations to granite.—Crystalline limestone.

It is desirable, in considering the structure of the crust of the globe, to commence with the foundation whereon the superstructure is raised, and to proceed to examine each story upwards in succession. Having, therefore, taken a general survey of the manner in which the different rocks are arranged, and inspected the constituent parts of the elementary materials, we shall proceed to examine the characters of the compound rocks formed from them, and the manner in which they are disposed, from the lowest known rock in the series.

In adhering to the four leading divisions of primary, transition, secondary, and tertiary formations, it must be observed that there are generally, no well defined boundaries between the lower formations and those that rest upon them. The notion that gave rise to the division of primary and transition, has been proved by subsequent investigation to be incorrect; for though the organic remains of the transition series are few and simple, it is possible that the cause may be found in the destruction of other organizations by the heat to which it is evident the lower rocks have been subjected; and the operation of the same force, more intensely exerted, may have entirely destroyed traces of former life from the rocks that are called primary. There is, however, another reason for retaining this classification. Primary rocks, if we include crystalline limestone among them, contain all the elementary materials of which the crust of the globe is composed; and this fact, combined with the absence of all traces of organization, presents sufficient distinction to justify the maintenance of the boundary line.

Granite, the lowest rock in the series, is a compound of felspar, quartz, and mica, in various proportions. These approximate elementary minerals, though mingled together in granite, are separated from each other in crystals, so that each component part can be distinguished. In specimens of granite from different localities, the forms of the crystals, and the colour of the felspar and mica differ, and they are of different degrees of hardness; but in all granitic rocks, the constituent minerals are closely united into a compact mass, having a granular appearance.

Granite is generally acknowledged to be the oldest of known rocks; though from its compound nature, it may be inferred that the constituent rocks must be older than their compounds. The felspar predominates, the quartz is the next in quantity, and the mica forms the least but most distinguished ingredient. The mass is crystalline, as if it had been cooled slowly from fusion, each component part having separated during the process into distinct crystals that adhere closely together. It might be assumed, as granite consists of three elementary materials which have different degrees of fusibility, that the most infusible would be the first to become hard on cooling, and that the others would separate from it in distinct crystals. It is probably owing to this difference in their degrees of fusibility, that the crystals of quartz, felspar, and mica become separately distinguishable, and that they are not combined together in one uniform mass. The different circumstances under which the molten granite has been cooled, have no doubt occasioned the varieties in the sizes and distinctness of the crystals.

The varieties observable in the composition and appearance of granites in different parts of the same country, and even in the same mountain, show that there is no one form of granite that can be regarded as the type of the general foundation of rocks. In Cornish granite, the felspar is white and undergoing decomposition; in the granite of the Malvern Hills, hornblende is substituted for mica; the Cumberland and Scotch granite is red; in the Dublin mountains it is white and compact; and in granite veins near Aberdeen, the felspar and mica appear as if they had more completely separated in cooling, the one forming large red crystals, and the mica being in thick plates.

In the section fig. 2, representing the general arrangement of strata, the granite is seen at the greatest elevation, but this is far from being generally the case; for the force that upheaved the rocks might not have been sufficiently powerful, or it might have been too deeply seated, to have forced the granite through the superincumbent strata. The highest point at which granite has been found is at the summit of Mont Blanc, 15,680 feet above the level of the sea. This feature of the Savoy Alps indicates that more energetic force was exerted to elevate that mountain-range than any other on the face of the globe; or, at least, that the force emanated from some point nearer to the surface than in the elevation of the more extensive and loftier mountains of the Andes and the Himalaya. In the Savoy Alps, the granite peaks protrude several thousand feet above the adjoining beds of limestone, which are inclined almost vertically, and some of the beds that have been tilted up into that vertical position, contain rounded pebbles and other water-worn fragments, which prove that before these strata were upheaved, they formed part of the bed of the ocean. In the Himalaya, the granite is not raised above one half the greatest height, the summits of the mountains being composed of the superincumbent rocks. It would, appear, therefore, that the internal convulsion which lifted the granite in that range of mountains, was not sufficient to force it through the strata above.

Granite does not appear at the summits of the highest mountains in England and Wales. In Cornwall it is found, at an inferior height; also in the comparatively low elevations of the Malvern Hills and Charnwood Forest; it comes to the surface at the foot of Skiddaw, in Cumberland; and it peeps forth in the north-west extremity of Wales.

The central parts of the principal mountain-ranges in Europe are granite. It appears in the Ural mountains in Asia, and it has been discovered in the mountains of Africa. In Canada and the eastern part of the United States, and along the extensive range of the Andes, granite occurs, but generally at a lower elevation than in Europe. In most places it is associated with similar kinds of rocks, if not exactly alike, so as to prove the universality of the geological arrangements observed in England. In South America, where volcanic agency has been exerted on an extensive scale, the primary rocks are overlaid with basalt and porphyry, which form the lofty pinnacles of the Andes.

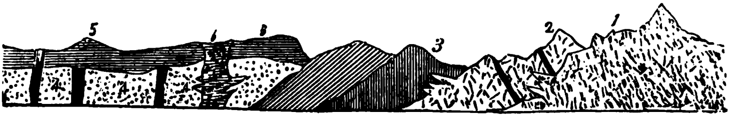
It seems evident, from the various structures of granite, and from the various circumstances in which it appears on the surface, that this foundation rock has undergone several changes; and that the protrusion of it through the superincumbent strata, has not been the result of any one convulsion, but that it has proceeded from internal actions at separate periods, of different degrees of force, and emanating at different distances from the surface. There are several instances also of granite resting for a limited extent on secondary strata, and of veins of granite forced through the superincumbent rocks; both which facts prove that such granite formations were more recent than the rocks they rest on and penetrate.

The appearance of granite in such positions does not, however, invalidate the received opinion that granite is the foundation-rock. All geologists now admit that the primary rocks were at one period in fusion, and that after they were solidified, and the upper strata had been deposited, basalt and other volcanic rocks were ejected in many parts in a molten state, and spread over them. Whence these masses of basalt came, if not from beneath the granite, it is not possible to conceive; and as it is a well-established fact that such immense masses of melted matter have been ejected from below, the few occasional instances of melted granite being likewise thrown on the surface, or forced through beds of solid rock, are only trifling exceptions to the general rule.

In the classification of rocks by Sir Charles Lyell, he adopts their supposed origins for the divisions and designations of their respective formations, calling the granites and porphyries Plutonic; gneiss, mica-schist, clay-slate, and crystalline limestone, metamorphic; and all the decidedly stratified rocks aqueous. He further makes a distinction between Plutonic and volcanic rocks, the latter being called igneous. The chronological order of classification seems, indeed, peculiarly inappropriate, if the relative ages of the rocks are estimated from the periods at which they were raised to their present positions; but if we regard the order in which the strata were originally deposited upon one another as the test of age, and consider the subsequent upheavings merely as modifications of the form of the pre-existing rock, the term primary may be consistently retained. If, on the other hand, the mode of formation be adopted as the distinguishing features of classification, all the rocks might be classed in two divisions only; for there are no decidedly marked distinctions between the Plutonic and the volcanic; and the metamorphic rocks, which usually rest on granite, are also considered to have derived their crystalline structure from the action of heat. The difference in appearance between primary and volcanic rocks is supposed to be owing to the different circumstances under which they were cooled; the former having been cooled slowly at a great depth, and consequently under immense pressure, whilst volcanic rocks were exposed to the air by being ejected on to the surface.

In the Highlands of Scotland, there occur some remarkable deviations from the general order of granite arrangement. The Isle of Arran, in the direction from north to south, presents striking illustrations of two distinct granite formations, which are represented in the annexed section:

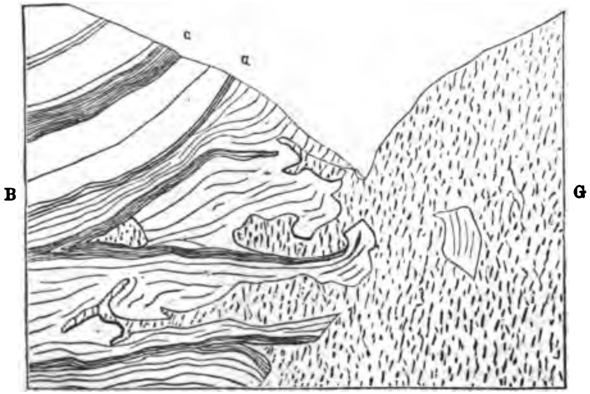
fig. 6.



The highest peaks of granite are 3000 feet above the level of the sea. The granite No. 2, intersected by veins, has been upheaved through the rocks that now rest upon it, as is shown by the granite veins forced into the gneiss, No. 3. A bed of sandstone (4, 4) is remarkable as not containing any pebbles of granite, though it abounds in the débris of the gneiss, and other rocks that rest upon it. This absence of granite fragments indicates that the bed of sandstone was deposited before the granite came to the surface, and that it has either been since forced through the gneiss, or that the overlying rocks have been swept away, and left it exposed. But the most remarkable feature of the section is a second granite formation, No. 1, differently grained from the former, from which veins penetrate into the granite through which it passes; evidently showing that it has been forced, in a melted state, through the overlying rocks, after they had been deposited and solidified.

Glen Tilt, which is renowned in tourists' annals for the struggle to force the pass and maintain the public right of view, presents some remarkable junctions of the granite with the adjoining rocks of limestone and argillaceous schist. They are described and figured by Dr. MacCulloch, in the first volume of the "Transactions of the Geological Society," one of which is represented in the accompanying section. The rock, B, on the left, is composed of limestone, with strata of blue argil-

fig. 7.



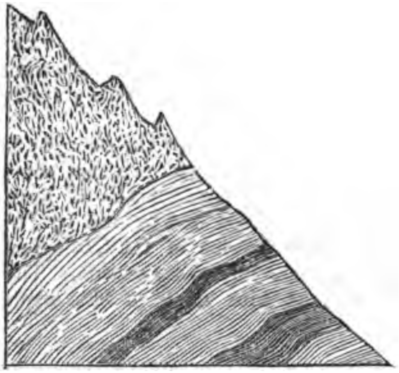
laceous schist, *a, a.* The rock, G, on the right, is granite; it will be observed, that the two rocks have mingled together, and detached masses of each are separated from their parent rocks, and are embedded in the other.

The positions of the granite and its branching veins, shown in the preceding sections, clearly prove its igneous origin, and that it was ejected from below at different periods, far apart. But if any further proof were wanted, it is to be found in the junction of granite with limestone, described by Dr. Mac Culloch as occurring in the Western Isles; and as it is seen also in the Alps near Champoleon (fig. 8).

The beds of limestone at a distance from their junction with the granite contain fossils, and the limestone is not crystalline; but a decided change in structure takes place as it approaches the granite, until it assumes the crystalline appearance of primary limestone, and no trace of fossil remains, the heat of the melted mass having completely altered its character from that of ordinary carboniferous limestone into statuary marble.

In the annexed diagram, the upper portion represents the granite which partially rests on the limestone, and the lighter shading of the parts near it shows where the limestone has been made crystalline.

fig. 8.



The variations in the structure of different granites have induced geologists to give them distinguishing names. When hornblende becomes the substitute for mica, it is called sienite, which has a smaller grain than common granite; when talc is an ingredient, the mineral is called talcose granite; when felspar predominates, almost to the exclusion of quartz and mica, it receives the name of felspathic granite, or eurite; and when the crystals of felspar are large and distinct, porphyritic granite, or porphyry. In all these varieties, however, the granular structure, derived from the separate crystals of its component parts, is preserved.

The rock that is most commonly found resting on granite closely resembles it in the constituents of its formation, and is supposed to have been formed by disintegrated fragments of granite, which have been deposited from aqueous suspension and subsequently crystallised by heat. This mineral retains the name of gneiss, given to it by German miners. It contains more mica in proportion than granite, and is disposed in a schistose or slaty state, attributable to the fine flakes of mica which appear to be arranged in a laminated form.

Granite and gneiss are so intimately blended that they frequently pass into one another by imperceptible gradations. When the mica becomes abundant, granite is converted into gneiss; when the felspar and quartz again predominate, it returns to granite. Gneiss seldom occurs in this island south of the Forth and Clyde, but it is well developed in the Hebrides and in the north and north-west of Scotland. It constitutes the principal geological feature of Norway and Sweden; it occurs in most of the mountain ranges in Europe, and in Brazil it occupies an extensive district, being the uppermost rock of mountains and valleys.

Gneiss passes almost imperceptibly into mica-slate, or micaceous schist, as it is indifferently called; the term schist being used to denote rocks of a slaty character. In this mineral quartz and mica predominate, and felspar is deficient, if not altogether absent. Mica-slate is often divided into laminæ by very thin layers of quartz and of crystalline limestone, and its structure approaches near to that of slate. Micaceous schist resembles gneiss in its gradual transition into granite, the variations in structure having been produced by different proportions of felspar and by the different actions of heat. Mica-slate often contains garnets and crystals of other minerals, which occasionally become so abundant as to be constituent portions of the mineral. In mica-slate and gneiss, ores of most of the metals are found.

Intermingled with gneiss and mica-slate are hornblende-schist and chlorite-schist, in which hornblende and chlorite are combined with felspar, quartz, or mica, in a slaty form. Those rocks have no well-defined position in the geological series, hornblende being a mineral that enters extensively into the composition of rocks possessing different names and characters. As hornblende-schist, it occurs only in the Grampian Hills in this island, but it is found in large beds in the mountain ranges of Europe. Chlorite-slate is soft and feels soapy, owing to the large proportion of magnesia it contains. It often intermingles with mica-slate and common slate, with which it occupies an intermediate position; and it also approaches to hornblende-slate, and to serpentine, all those rocks being apparently modifications of the same.

Serpentine is the form in which hornblende occurs when combined with chlorite, and sometimes with crystalline limestone. Its beautiful variegated green colours, and the high polish of which it is susceptible, peculiarly adapt it to ornamental purposes, for which it is much used. It possesses the advantage, when compared with marble, of being harder and not liable to be injured by acids. One variety of serpentine, in which limestone is imbedded, constitutes the much valued *verd antique*. The western extremity of Cornwall, near the Land's End, is the only part of England in which serpentine is found. It also occurs on the north-west of Anglesea, in southern declivities of the Alps, and in the United States; but as a rock formation, it is of limited extent. Some softer kinds of serpentine, called pot-stone, the *lapis ollaris* of the ancient Romans, are worked into vessels for common use.

Crystalline limestone is essentially distinguished from the primary rocks, with which it is associated, by its elementary constituents. Lime enters very sparingly into the composition of the other primary rocks, but in this mineral it forms the principal part, in combination with carbonic acid. In its purest state it is perfectly white, and when broken its fracture resembles that of fine loaf sugar, from which appearance the French geologists have given it the misleading name of *chaux carbonatée* *saccaroide.* Crystalline limestone usually rests upon mica or chlorite-slate, with which it sometimes intermingles, showing that those rocks were at the same time in a fluid or semi-fluid state.

CHAPTER IV.

LOWER TRANSITION ROCKS.

Characteristics of the transition series.—Organic remains.—Slate rocks: their characters and cleavage.—The "Silurian System," lower and upper.—Fossils of the Dudley limestone.—Peculiar elevation of limestone hills.—Old red sandstone: its intimate relation to rocks below and above it.—Fossils of the Devonian system.

Resting on the primary rocks, and passing into them by gradations scarcely to be distinguished, are the transition rocks. These rocks, like gneiss and mica-slate, may be considered to have been formed from fragments of granite, combined with limestone and with carbon, which first appears as a component part of rocks in the clay slate, that rests upon, and is often blended with the primary schists.

The transition rocks are more distinctly stratified than the primary, and generally afford evidence of having been deposited from suspension in fluids. Though the action of heat is less conspicuous in them than in granite and the primary rocks, there are numerous indications of the operation of that powerful agent in consolidating the transition rocks after their deposition. It has imparted to the limestones, which constitute an important part of the series, a structure and hardness approaching to crystalline: and the numerous crystals that abound in the cavities of that rock, as well as the crystallized lead ores it contains, are corroborative evidence of the agency of heat.

The marked feature, however, of the transition formations, is the presence, in most of the rocks, of the organic remains of a former world. As such remains occur first in the lower rocks of the transition series, geologists formerly considered this dawn of organic life to prove that the creatures which lived at the period immediately preceding the formation of these rocks must have been the earliest of animal existences. This opinion, we have before stated, has since undergone some change, and it is now supposed that living creatures might have previously existed on the earth but that all traces of them have been removed by the subsequent fusion of the rocks in which they were imbedded. This supposition derives strength from the fact, that the organic remains which are first discovered in ascending from the granite are those of marine animals, with scarcely any traces of plants. It is evident that such creatures must have had food to subsist on, yet the remains of marine plants are rarely seen associated with the animals that fed on them. It is, therefore, inferred that the heat to which the rocks wherein such remains occur was subjected, must have destroyed the indications of vegetable life, though not sufficiently intense to efface the less destructible animal organizations. Another inference drawn from this destruction of the remains of vegetable life is, that the higher degree of heat which fused the primary rocks might have effaced all impressions of antecedent animal existence.

Examination of the fossilized remains of the first known occupants of the world, tends to throw some light on the condition of our planet at the period of their existence, and enables us to perceive whether the ocean they lived in was turbid or clear, and whether the atmosphere was stormy or tranquil. These interesting revelations of the physical geography of a former world, are made by a marine animal called the trilobite, (represented in figures 9 and 10, in different positions). It is one of the earliest forms of life of which the remains are preserved in the lowest fossiliferous transition rock. A microscopic examination of the eyes of that creature shows, that they were constructed of a number of small lenses, specially adapted to vision in clear water with a tranquil atmosphere above it.* By the application of the principles of optical science to the observed structure of a minute fossil eye, we are thus enabled to ascertain, that notwithstanding the convulsions which had previously broken the crust of the earth, and the vast accumulations of mud from which subsequent strata were deposited, there were long intervals of repose, during which generations of creatures enjoyed existence in pellucid oceans of tranquil water.

fig. 9.

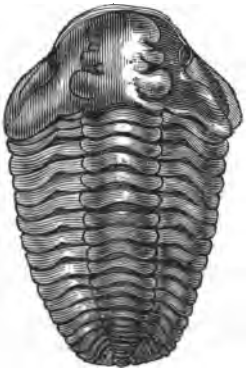
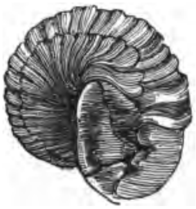


fig. 10.



The lowest of the transition rocks are the slates, which bear marks of having been composed of fragments of the primary rocks, deposited from aqueous suspension, and afterwards consolidated and partially crystallized by heat. In some slate rocks the congregated fragments are large and angular, in others they are small and waterworn. They are embedded in a cement of alumina or argillaceous earth derived from the decomposition of felspar, and this cement varies in quantity as much as the fragments it binds together vary in size. The peculiar cleavage of slates in parallel lines, constitutes the chief distinction between them and many of the rocks with which they are associated. This disposition to separate in regular layers was formerly attributed to stratification; but subsequent examination has shown that, with few exceptions, the line of cleavage is at a different angle from the line of the beds. The direction of the cleavage generally makes an angle of about 60 degrees with the direction of the strata.

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* Dr. Buckland's Bridgewater Treatise.

The slate rocks constitute an important formation. They are distinguished by several names; the coarser kinds having received the strange, unmeaning name of greywacké slate, adopted from the German nomenclature, and still in common use. Greywacké slate passes by gradations into a finer kind of slate, sometimes called clay slate, of which common roofing slate is a specimen. Greywacké also frequently occurs without a laminated structure, and forms in that state a coarse kind of sandstone. Slate, greywacké, and sandstone have the same origin, and similar constituent parts, being all of them derived from the materials of granite and its associated rocks; the difference in their appearance depending on the various circumstances under which they were formed into rocks at different periods. In many instances the slate passes into sandstone, and sandstone into schist by such gradual transitions as to show that there was no distinct epoch between the periods of their formation, and that their differing characters were occasioned either by slow changes during the process of deposition or by the partial action of heat, the effect of which has not penetrated through the mass. Even in the same mountain range the quality of the slate varies considerably, according to the predominance of the subjacent rocks, and when siliceous material prevails it becomes converted into a kind called flinty slate.

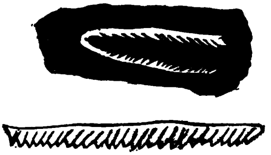
The occasional occurrence of impressions of shells and sea weed in beds of slate, and their more decidedly stratified forms, seem to remove them from the class of primary rocks; but their position in the geological series is not decidedly marked, and geologists differ respecting the formation with which slates should be associated. As it is an established fact, however, that even among the secondary formations strata occasionally occur without any fossil remains, the partial absence of such indications does not afford sufficient reason for classing slates with the primary rocks. It would greatly facilitate the progress of geological knowledge, if a more general system of classification were adopted, and such names were agreed upon for rocks as would impart definite ideas of their constituent parts and of their relative positions in the geological series. The class of slates and sandstones, for instance, having been formed by the decomposition and disintegration of primary rocks, they might be included in one generic term, and be numerically distinguished according to their crystalline structures and their ascertained orders of succession.

Slate rocks are generally very metalliferous, but in England they are chiefly worked for copper and lead. The richest copper veins of Cornwall are contained in a schistose rock called killas, that often lies immediately on granite, and is not always of a slaty structure. Slate is of common occurrence in mountain ranges, and in the Pyrenees two-thirds of the mountains are formed of slate. The outlines of slate mountains are serrated and picturesque, but they are not so precipitous as those of granite, because their laminated structure exposes them to the action of the atmosphere, and they are easily split into fragments, which rest on the declivities and form an inclining surface to the summits.

Above the great slate formation, and partially mingled with it, occur the lower beds which constitute what has been designated by Sir Roderick Murchison the "Silurian system." These rocks are well developed on the borders of Wales, in Shropshire and Radnorshire, a district occupied by the ancient Silures; and Sir Roderick has endeavoured to perpetuate the knowledge that such an obscure race formerly lived, by giving their name to a class of rocks which he successfully examined and determined the position of, and which is to be found more or less developed in most parts of the world.

The lower Silurian system is composed principally of what are called Llandeilo flags and Caradoc sandstones; which consist of sandy slate, sandstone, calcareous schist, shelly limestones and sandy limestones. These beds are estimated to be several thousand feet thick. The proportions of aluminous matter and quartz they contain is greater than in the upper series of strata, and the quantity of lime is less. The fossil remains in the lower Silurian beds are sufficiently abundant to prove that at the period of their formation, the earth was inhabited by living creatures; among which, the trilobite is conspicuous, though not so abundant as in the upper division of the Silurian series. A characteristic molluscous marine animal, called graptolite (fig. 11), is found in the Caradoc sandstone, and is almost entirely confined to that rock.

fig. 11.



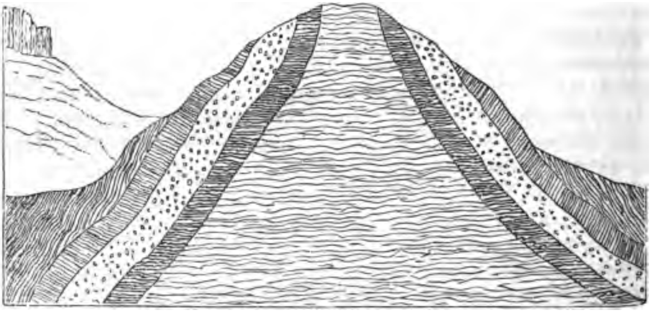
The upper Silurian system comprises a series of beds in which limestone predominates. They are named Dudley shales, Dudley limestones, and Ludlow shales, from the localities where they are best developed in England. The Dudley limestone and shale were formerly known as the transition-limestone. They abound in trilobites and corallines, and are estimated to be 4000 feet in thickness. The Ludlow rocks consist of dark calcined flags and shale, grey subcrystalline limestone and micaceous limestone.

This class of rocks is sometimes divided into the Wenlock formation, and the Ludlow formation. The Wenlock shale is generally of a muddy appearance, containing impure argillaceous and calcareous nodules, succeeded by impure, highly fossiliferous limestone-beds, separated by argillaceous matter. The Ludlow formation comprises two beds of shale with an intervening bed of limestone. The upper beds of the Ludlow shale pass into sandy beds that contain innumerable fossil fragments of small fishes of several kinds. The trilobite is particularly abundant in the Dudley limestone, and hence acquired the name of the Dudley fossil; and bivalve shells of the genus terebratula are very numerous.

The limestone at Dudley Castle Hill and at Wren's Nest Hill, which is about two miles distant, bear evidence of the action of internal force in their elevation above the surrounding country. The limestone consists of two beds, one ten, the other fourteen yards thick, which rest upon thicker beds of soft shale. Some force, which from the limited extent of its effects could not have been far below the surface, has elevated both hills in conical forms, so that the limestone surrounds the summits like two circular walls, which are almost vertical. At Wren Nest's Hill, they enclose a space of about fifty acres. At Dudley Castle

Hill, represented in the accompanying section (fig. 12), the strata are not so vertical, and rise more to a point. The opinion that igneous agency has caused the elevation of the limestone, is confirmed by the presence of basalt on some of the neighbouring hills, where it has been ejected in a melted state, and presents a columnar structure.

fig. 12.



Rocks agreeing in character with the transition-limestones or upper Silurian group, are met with in Belgium, France, Russia, Scandinavia, in North and South America, and in the Polynesian islands. The complete development of the Upper and Lower Silurian groups is estimated to be 7500 feet thick.

The next of the transition series in an ascending order is the Old Red Sandstone, which has been dignified with the name of the Devonian system. It is subdivided into three separate formations: first, a sandy rock, occasionally micaceous, called tilestone, which overlies the upper Silurian; next, a red limestone called cornstone and marl; and the third is the red conglomerate, which constitutes the red sandstone, whence the whole system derives its name.

Much importance has been attached to the old red sandstone as forming a marked boundary between the lower orders of rocks and the carboniferous series which contain the coal measures. Some geologists, however, regard it as a mere modification of the greywacké rocks, and from the circumstance of the gradual passage of one into the other, frequently observed, it seems that there is really nothing essential in the old red sandstone but its colour, derived from oxide of iron, to distinguish it from the lower sandstone formations; whilst its intimate connexion with the carboniferous shale above it, is clearly perceptible. The old red sandstone also passes into claystone, like that of the Pentland Hills. All these transitions tend to indicate that the mountain-limestone which lies above, with its alternating beds of grit, the red sandstone, and the greywacké, are members of the same formation.* The links in the chain of connexion between the lower and upper series of rocks, appear to be quite perfect in Belgium, where the limestones, which occur in the old red sandstone formation, are identical with the transition-limestone and with the carboniferous or mountain-limestone, on which the coal measures rest. On the other hand, many of the fossil remains in the old red sandstone formation, mark it as distinct from any of the rocks below or above it. One distinguishing characteristic is the abundance of the remains of fishes, which occur in the bituminous schists associated with the old red sandstone in Scotland, corresponding to fossils found in rocks occupying the same geological position in Russia. Some of these fishes are different from any found in the upper series of strata, and present the most extraordinary appearance. In one genus, the head and part of the body are covered with large, regularly-shaped plates, instead of scales. The cephalaspis (buckler-headed,) which belongs to this group, is represented in the annexed woodcut (fig. 13).

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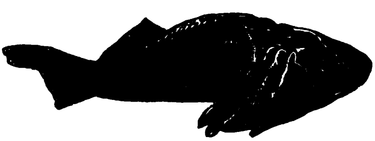
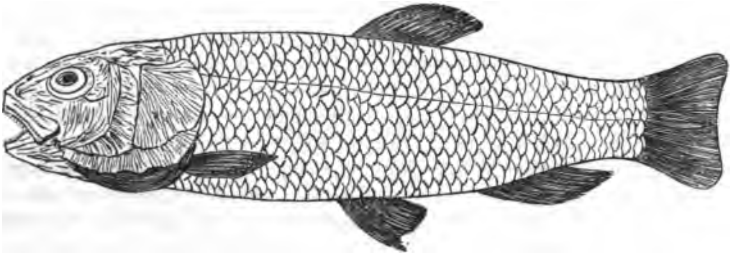
* Introduction to Geology.

fig. 13.



Other fishes, of which the dipterus (fig. 14) is the type, bear more resemblance to fishes of the present day; but there are characteristic peculiarities which distinguish it from any other species that lived before or since; and from its absence in the upper strata of the old red sandstone, it would appear to have soon become extinct. Most of these fishes were small, not exceeding two or three inches in length; but one genus, the holoptychius, attained a large size, and must have been very voracious. It was encased in scales of large dimensions, and possessed formidable teeth. One species allied to this genus is supposed to have been upwards of thirty feet long.

fig. 14.



A univalve shell, the clymenia, which exhibits the first change in the structure of the shell by which the nautilus passed into the ammonite, is exclusively confined to this series of rocks.

The old red sandstone is well developed in Herefordshire and Monmouthshire; it thins out, till it appears again in Westmoreland in thick beds, and farther north, in Scotland, it is exhibited on an extensive scale, spreading over a district one hundred and twenty miles in length; and having in some parts the thickness of several thousand feet. In Scotland, the intervening series of the Silurian system are wanting, and the old red sandstone rests immediately on gneiss.

Among the fossils that occur in the lower transition rocks, in addition to those already mentioned, are corallines, madrepores, a few species of bivalve shells, and the nautilus.

CHAPTER V.

UPPER TRANSITION ROCKS.

Character of the strata.—Carboniferous limestone: its supposed formation by coralline polypi.—Conjectured sources of the supply of lime.—Elevation of the carboniferous limestone into mountains.—Evidence of igneous action.—Caverns in limestone.—Stalactites and stalagmites.—Separation of limestone beds by igneous rocks.—Coal strata.—Changes in the condition of the world before their deposition. —Luxuriant vegetation of the coal period.—Strata that accompany coal.—Geographical distribution of coal.—Formation of coal.—Coal basins.—The disturbance of strata by faults.—Probable duration of coal in England.—Fire-damp in coal mines. —Suggestion for diminishing the danger of explosions.—Association of ironstone and coal.

THE upper transition formation comprises several distinct and important classes of rocks. The carboniferous system might with propriety be subdivided into the calcareous and coal formations, as they possess very marked distinguishing features; but the characteristic property, common to both, of containing large quantities of carbon, though in different forms of combination, has occasioned their being classed together; and we shall therefore adopt that order of classification.

The lowest strata of the carboniferous series consist of shales, or sandy slates, mixed with conglomerated beds which pass, in an ascending order, into imperfect limestones, and gradually merge into the bed of carboniferous or mountain limestone, of great thickness and extent, which forms the foundation whereon the coal strata rest in most parts of England. The underlying shales, which are in several places closely connected with the greywacké, or with the red sandstone of the lower transition series, do not possess much geological importance, except from their association with the mountain limestone above. The latter forms a very extensive range of rocks, rising in many parts of the country into picturesque mountain masses of great beauty. This limestone is well developed in the lofty hills of Yorkshire and Derbyshire, where the deep water-worn valleys and high precipices afford good opportunities for examination.

In the opinion of some geologists the mountain limestone is identical with the lower transition limestone of Dudley, since they occasionally pass into each other; but the distinction in the fossil remains shows that they were formed at different periods, and under different circumstances. Many of the beds of mountain limestone are composed entirely of the remains of marine animals of the coralline class; the prevailing characteristic fossils being encrinites and madrepores. The limestone is of various colours, and possesses different cohesive structures; but the chemical constitution is alike in all the varieties. It is a pure carbonate of lime, consisting of 57 parts of lime and 43 of carbonic acid.

The abundant remains of corallines indicate that this limestone was formed under water, in a similar manner to the extensive coral reefs that are at the present day in the course of construction by the same kind of polypi in the Pacific and Indian oceans. These recently formed rocks, which extend for hundreds of miles, are constructed of the outer coverings of the extinct polypi, to which generations in succession have attached themselves, until the increasing mass of shells rises to the surface, and there the progress upwards ceases.

Opinions differ respecting the depths at which the coralline polypi can live. It appears from some researches, that the coral reefs are based on volcanic rocks, or submerged islands, originally not more than twenty or thirty yards below the surface; but in other places, some species of coral have been found at depths exceeding two hundred yards. In the immediate vicinity of coral reefs the sea is frequently very deep, which gives countenance to the opinion that the coralline products must be formed on the tops of submarine precipices; for whether we limit the range of life under the sea to 200 or to 500 yards, it cannot be supposed that life could be sustained at the profound depths to which soundings have reached close to the coral reefs in the Pacific.*

It is a subject for curious speculation whence the polypi, both of ancient and of existing species, derived the lime that is collected in such abundance in their shells. The water of the ocean, which seems to be the only source of supply within reach, as the polypi have no locomotive powers, contains only a minute portion of calcareous matter. In the absence of any known source whence the lime could have been obtained, it has been surmised that the coralline polypi possess the power of decomposing sea-water into its ultimate elements, and of thus producing, by a recombination of elementary matter, the lime that is required for their shells.

The action of heat is sufficiently evident in the mountain limestone, though it has not been so intense as that to which the primary limestone must have been subjected. The uplifting of the mass of coral structure, which must once have been below the level of the sea, to its present position, affords, indeed, ample proof of igneous agency. In several parts of Derbyshire, the comparatively local action of heat in lifting up and bending beds of mountain limestone are very remarkable. At Crich, near Matlock, there is an isolated rock 900 feet above the river, in which the strata rise all round, and enclose it in concentric circles, indicating that the rock has been uplifted by some force acting in the centre, and not far below the surface. This inference, which geologists would draw from inspection of the position of the strata, has been satisfactorily proved by driving a horizontal gallery into the cliff in searching for lead. After penetrating through the strata of limestone, the miners arrived at a nucleus of a volcanic rock called toadstone. The same fact was ascertained by sinking a shaft perpendicularly into the rock. The annexed section, made by the late Mr. R. Bakewell, exhibits the arched stratification of the limestone, with the volcanic rock, *b*, in the centre. On one side of the hill there is an opening filled with lead ore, and there are rich metallic veins in other parts of the rock. The lower portion of the hill is surrounded by shale and gritstone, represented at *c*, *d*.

The beds of mountain limestone are frequently cavernous, large open spaces having been worn away by the action of running water. The caverns in the High Peak, at Buxton and at Matlock, are of this kind. They extend for considerable distances into the rocks, and are in many parts covered with crystals of calcareous spar, which glitter with great brilliancy, and when lighted up convert the gloomy paths through the mountains into beautiful grottos. In these caverns there are streams of running water, which descend through crevices in the rock from the surface, and flow down to unexplored caverns below. The action of these currents for countless ages has, no doubt, enlarged original crevices into the large open spaces that are now seen.

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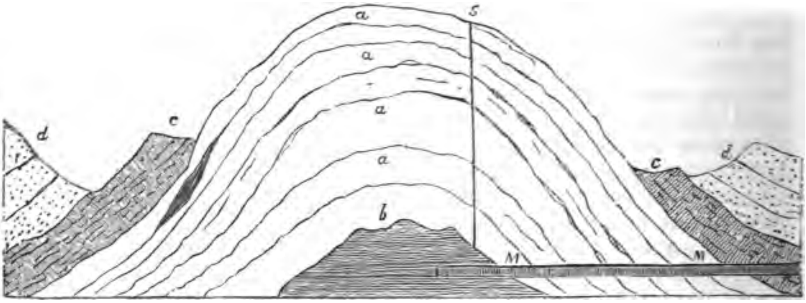
* The result of Professor E. Forbes's dredgings in the Egean Sea led him to conclude that the range of animal life does not extend below 230 fathoms.

fig. 15.



The water that percolates through the fissures in these rocks absorbs, by the aid of carbonic acid, a quantity of lime, and when exposed to the air, the dissipation of the carbonic acid gas, and the evaporation of the water, cause the lime to be deposited. The constant dripping of the water from the roofs of the caverns tends, in this manner, by chemical reaction, to fill up the chasms worn away by mechanical attrition. The gradual depositions of limestone on the floors of the caverns form the rising mounds, called stalagmites, and the inverted pinnacles on the roof constitute stalactites, which in some caverns meet and close up the cavities. When the water is strongly impregnated with lime, the depositions take place so rapidly that any articles immersed in it become soon covered with lime. "Petrifying wells," as they are called, do not, however, fossilize the things put into them; for if the articles be broken, the original structure will be seen, the deposition of lime being only external.

The mountain limestone is very rich in lead ore, which is found in veins, traversing it in various directions and in different forms. The limestone of Derbyshire also contains detached beds of fluor spar and of crystalline gypsum or alabaster, both of which are wrought into ornamental vases of great beauty. The fluor spar mine near Castleton is separated from the limestone rock by a lining of sulphate of barytes and by a thin layer of unctuous clay. The roofs and sides of the natural caverns in this mine are crystallized more beautifully than any other caverns in England, though they are little known to tourists, and are seldom visited, on account of the lowness of the roof in some places, which renders the access not so easy as in the other caverns.

The mountain limestone of Derbyshire is separated into four beds, divided from each other by the volcanic rock called toadstone, which is allied to basalt. The two upper beds of the limestone, as they occur near Matlock, are each 150 feet thick, the third is 160, and the thickness of the fourth is not exactly ascertained. The thickness of the beds of toadstone that separate them varies considerably, but they are generally thinner than the limestone. This succession of volcanic rocks between the limestone points out their successive periods of formation, and indicates, in the construction of these rocks, as in that of recent coral reefs, the close association of the structures of coralline polypi with volcanic deposits. It seems probable that each bed of limestone, when brought to the surface by the polypi, was successively covered by volcanic eruptions, which, at the same time, raised the bed of the sea, and again covered the surface with water; succeeding generations of polypi then renewed their labours and constructed a second bed, which was again overflowed with lava and once more covered by the sea. Another remarkable fact in connexion with the structure of these rocks, which invites the attention of the speculative geologist, is, that as coralline polypi live only in warm climates, the temperature of the northern parts of the world, where the rocks formed by them occur, must have been formerly much warmer than at present. This inference is confirmed by the fossil flora of the overlying coal measures, for the plants found in them are principally those of tropical climes.

Mountain limestone occupies nearly the whole of the central part of Ireland, and extends west to the mountains of Galway. In England, it reaches from Somersetshire through Derbyshire into Yorkshire; it extends over a great part of central and northern Europe; it occurs among the lakes of North America, and is found on the borders of the Arctic Sea.

The coal strata indicate a geological epoch, separated, by numerous intelligible and decisive marks, from the preceding periods of rock formations, and clearly show that an important change must have taken place in the condition of the globe before they were deposited. All the lower rocks we have hitherto noticed bear manifest evidence of subaqueous formation. The organic remains are, with few exceptions, those of marine animals; and there is little doubt that, during the long periods occupied in the gradual decomposition of rocks and deposition of slates and sandstones, the earth was covered by the sea, as it must have been also in those parts where the mountain limestone is found.

But the rocks we have now to examine differ in essential points from those whereon they rest. The strata immediately associated with coal, and usually called the coal measures, abound in the remains of vegetables and plants that flourished on dry land, and in a hotter, if not in a tropical, climate. The remains of marine animals are comparatively few, whilst there are seen distinct traces of fresh-water formations and extensive forests. That large amount of vegetable matter indicates, of course, an abundance of carbon—an element which is of rare occurrence in the lower rocks, except when combined with carbonic acid in lime. Another striking indication of change in the condition of the globe is seen in the generally unconformable positions of the coal strata to those on which they rest. This would almost necessarily result from the sedimentary depositions having taken place after the crust of the earth had been lifted up above the level of the sea, for the subsequent strata would lie horizontally on the top of those previously inclined by the upheaving force. It must not be supposed, however, that the formation of the strata of the coal measures was independent of the action of water. Though formed after the land had been raised above the level of the ocean, every successive layer of carbonaceous matter and of sandstone shows that the land was, at so many successive intervals, covered by water; but the characteristic difference is, that, in the formation of the coal measures, fresh-water was the agent.

As the coal measures were formed after the land had been raised above the sea, and were, consequently, deposited in districts separated from each other, and at different levels, each valley of deposition exhibits, as might be supposed, local peculiarities; therefore the same correspondence in the order of succession cannot be looked for as prevails generally among the rocks deposited under the sea. In North and South Wales, in Shropshire, Derbyshire, Yorkshire, Lancashire, Northumberland and Durham, the coal measures rest directly upon the mountain limestone; but in South Staffordshire, that limestone is wanting, and they rest on the limestone of the lower transition series, whilst in Scotland the old red sandstone forms their foundation.

The lowest bed of the coal measures, which separates them from the underlying rocks, varies from a soft slate to a hard sandstone. This bed, called limestone shale, is, in some places, 600 feet thick. It is composed of a series of thin strata, some of which are so soft as to crumble when exposed to the atmosphere. The high cliff of Mam Tor, near Castleton, is formed of this soft kind of shale; and, as it is constantly peeling off, it has obtained the name of "the shivering mountain." This lowest bed of the coal series contains numerous vegetable remains, and sometimes thin seams of coal, but none of any value. It is remarkable that when this bed rests on the mountain limestone, the lower strata frequently contain marine exuviæ mingled with those of fresh-water animals, showing that, at the period of their deposition, the bed of rock was nearly on the level of the sea, which from time to time covered it.

The next overlying bed consists of a harder kind of sandstone, which sometimes contains fragments of quartz. It varies in structure from a coarse grain to a remarkably fine kind of sandstone; and from the circumstance of its having been used to form millstones, the whole bed has acquired the name of millstone grit. This bed is about 500 feet thick. It contains numerous fossil vegetables, but no seams of available coal.

Resting upon the millstone grit are the strata more immediately associated with the workable beds of coal. The coal, however, forms but a comparatively small portion of the strata, which exceed 400 yards in thickness. This great deposit consists of a succession of sandstone, ironstone, indurated clay, argillaceous strata, called "bind," and shales. There are also interspersed among some coal strata argillaceous layers, containing numerous shells of fresh-water muscles, called by the miners "muscle bind."

The regular coal formation has never been found at great elevations, and it generally occupies the valleys near mountain ranges. So far as geological knowledge of the different countries on the globe extends, coal is principally found between the latitudes 35 and 65, neither extending into the tropics nor into the arctic regions. Of the countries in Europe, England, Wales and Scotland are the most bountifully supplied with mineral fuel. Belgium ranks next. Silesia, Saxony, Bohemia, and Thuringia possess extensive beds of coal; and though Belgium now possesses the best portion of the rich coal field in the north-eastern part of France, there are other available coal strata in the western, the middle, and the southern parts of that country, especially in the neighbourhood of Lyons. In the more southern and in the northern parts of Europe, coal is of rare occurrence.

In North America coal is very abundant. It extends in Pennsylvania over a district of three hundred miles; and it is also found in other parts of the United States, along the great valley between the Alleghany and the Rocky Mountains. The only great coal formations in Asia that are yet known occur in China, where mineral fuel has long been used.

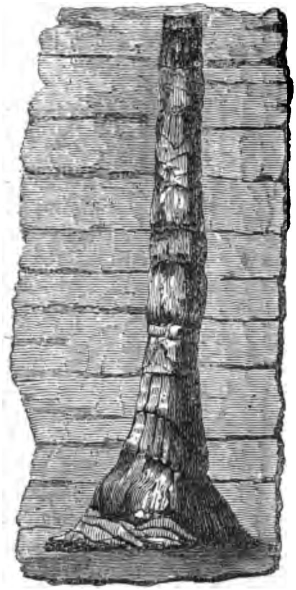
The principal coal districts in Great Britain are those of Northumberland and Durham, which extend over an area of about 1200 square miles, with an average thickness of twelve feet of coal. The Lancashire and Yorkshire coal beds cover a space of 1500 square miles; those of Staffordshire, Shropshire, and Warwickshire, 280; the coal field of South Wales extends over 1200 square miles, and there are important coal strata in the south of Scotland equal in extent and in thickness to those of Northumberland and Durham. In addition to these principal depositories of mineral fuel, there are coal fields of smaller extent in Somersetshire, Leicestershire, and the western part of Cumberland.

There has been much speculation on the probable causes of the formation of coal. All geologists seem, however, to be now agreed that it is the product of decomposed vegetation; but opinions differ respecting the nature of the plants from which coal was formed, the processes and changes that the vegetable substance has undergone during its conversion into mineral coal, the source whence the carbon that forms so essential a part of the composition of plants was derived, and their condition as to growth or accumulation at the time of conversion into coal. The impressions and remains of vegetables in the coal itself, and in the accompanying strata, are sufficient to point out the source whence it was formed; but if any doubt existed as to the origin of coal, it would be removed by the evidence of the gradual change of wood to mineral fuel, which is afforded in the half-converted kind, called wood-coal. This coal is found deposited in beds many feet in thickness, at Bovey Heathfield, near Exeter; and it is still more completely developed near Cologne, where it extends over a space of several leagues, in beds fifty feet thick. It rests on clay, and is covered by beds of gravel, being evidently a more recent formation than that of common coal. In this coal, the trunks and roots of trees only partially mineralised, are seen in the upper parts of the beds; and lower down, the vegetable matter is consolidated and converted into a substance closely approaching hard mineral coal. Nuts indigenous to China and India, and a fragrant resinous substance called retinasphaltum, have been found in it. In common coal there may be frequently seen impressions of vegetables;

and the thin layers that are sometimes intermingled with the sandstone seem, by the impressions with which they abound, to have been comprised entirely of the leaves of plants.

The remains of vegetables in the regular coal strata are those of land plants allied to the growth of tropical climates at the present day, but of a larger size than any known living species of the same genera. Tree ferns, gigantic equisetæ (horse tails), pines, lycopodiæ, allied to ferns, and trunks of trees called sigillaria, constitute the largest portion of the fossil remains that accompany coal. In many instances, the stems of large trees are to be seen erect, from which it is inferred that they grew where they are found; though the prostrate positions of most of the stems, and their separation from the roots, indicate that they were broken by hurricanes, and were drifted and heaped together by floods, before the process of conversion into coal commenced. The accompanying figure represents a trunk of the sigillaria imbedded in the shale.

fig. 16.

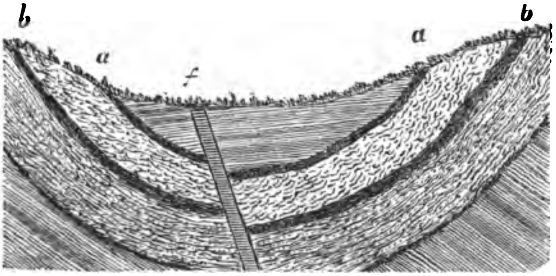


The very luxuriant vegetation of the period of the coal formation shows that the condition of the earth and of the atmosphere must have been peculiarly favourable to vegetable life. It has been conjectured, and with great probability, that at that time the atmosphere contained a greater proportion of carbonic acid than at present. Such a condition of the air would be highly favourable to the growth of plants; and as the carbon that is secreted during the process of vegetation is almost entirely derived from the atmosphere, we need not look beyond atmospheric sources for the supply of that elementary material. Carbonic acid, which consists of carbon and oxygen combined in the proportion of 27 to 73, forms, as before noticed, an important constituent of limestone; and such vast quantities of carbon are stored up in that form in mountain-masses, that it is estimated the calcareous ranges of the Jura and of the Alps contain sufficient to form a bed of pure solid carbon, one thousand feet thick, covering the whole extent of those mountains.

During the ordinary process of vegetation, the carbon is abstracted by the leaves from the oxygen with which it is combined in the atmosphere, and is assimilated into the fibres and tissues of plants, whilst the oxygen thus liberated from the combination adds to the vital properties of the air. Supposing that the atmosphere contained more than its present proportion of carbonic acid, the abstraction of the carbon by the leaves of plants would thus fit it more completely for the support of animal life; and this period of prolific vegetation might be considered as preparatory to the appearance of air-breathing animals on the earth.

Several coal fields bear striking indications of having once formed the beds of lakes. The strata are curved into hollows, and lie within one another, like a series of gradually diminishing basins. The occurrence of this arrangement of strata has caused the term "coal basin" to be applied to a confined district of coal, in which the strata are so placed. The thickness of the seams of coal in such cases is frequently greater in the centre than at the edges, where they thin out at the surface, and become imperceptible. The accompanying section represents a basin of this kind, in which the strata have been disturbed by what miners call a "fault."

fig. 17.

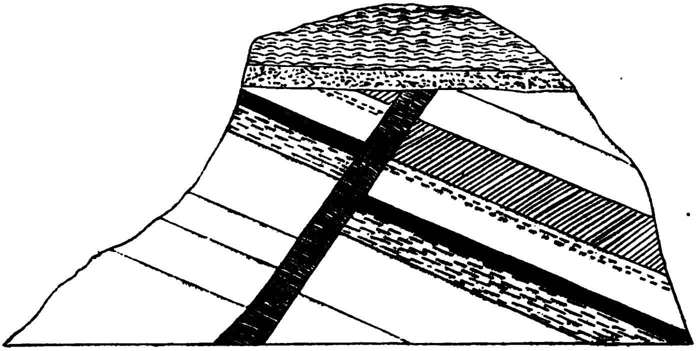


Faults are of very frequent occurrence in coal fields. They mostly consist of thick walls of basalt protruded through the strata from below, which have lifted up one side and depressed the other. In the strata represented in the section for instance, *a a* and *b b* are seams of coal that originally were continuous, but have been broken and thrown into the positions shown by the irruption of the mass of basalt at *f*, which descends as far down as it has been possible to penetrate. When a fault is in an inclined position like that in the section, it is found to be an almost invariable rule, that the strata are lifted up on the side towards which it leans, and are depressed on the other side. These faults, or "dikes" as they are frequently called, are not always occupied by igneous minerals. Sometimes, there is nothing but a cleavage in the strata filled up with the disrupted rocks on each side; and in the beds below the coal, these faults are often filled with metalliferous ores. The extent to which strata are separated by faults varies from one yard to a thousand.

The phenomena of faults present remarkable appearances, which are difficult satisfactorily to explain. Not only is the elevation of the strata on one side, and the depression on the other to be accounted for, but the removal of the uplifted strata and their levelling with the surface, remains to be explained. What has become of the masses of strata lifted up above the rest? This question suggests itself on looking at the preceding section, for the surface, it will be observed, presents no appearance of irregularity, yet it is almost certain that the elevated strata must at one time have formed an abrupt precipitous hill. The same fact seems still more extraordinary, when the disturbed strata have been covered by subsequent depositions, after the surface has been levelled, as in the annexed section of Quarrington Hill, near Durham, (fig. 18.) The strata have been raised by a basalt dike, to the height of twenty-four feet; and after the surface had been levelled, beds of magnesian limestone and new red sandstone have been deposited unconformably upon them.

As an abundant supply of coal is essential to the manufacturing prosperity of this country, it becomes an interesting and important question, whether the supply is likely to be exhausted. Many estimates have been formed of the probable duration of coal in England, founded

fig. 18.



on the extent of the seams of coal now worked, and on the annual consumption. When it is stated that more than one-third of the coal-seams in Northumberland and Durham has been already worked out, and that the consumption of coal now quadruples what it was thirty years ago, there may seem to be cause for apprehension of an approaching decline of England's manufacturing pre-eminence. The annual consumption of coal, in the manufacture of iron alone, is nearly ten millions of tons; and the total annual exhaustion of the coal mines, including waste, cannot now be stated at much less than forty millions of tons.* Dr. Buckland and Professor Sedgwick, twenty years ago, estimated the probable duration of coal in England to be about three hundred and fifty years. Since that time, the consumption has been greatly increased; therefore, if the present workable coal-seams in England were the only sources of supply, two hundred and fifty years would probably see them exhausted. But the South Wales coal formation, which has yet been comparatively little worked, contains stores of mineral fuel that will last for many additional hundreds of years. It extends over twelve hundred square miles, and the total thickness of the workable coal-seams is ninety-five feet. Each square mile, it is calculated, will yield sixty-five millions of tons; therefore, even should the annual consumption of coal increase to sixty-five millions of tons, there would still be a supply for 1400 years to come. A great part of the coal in South Wales is of the kind called anthracite, which consists principally of carbon, burns without flame, and is difficult to ignite.

The difficulty in mining for coal is greatly increased by the constant evolution of carburetted hydrogen gas, which issues from the fissures in the coal beds, and fills the passages of the mines with explosive mixtures of carburetted hydrogen and atmospheric air. In mines where the pillars of coal that supported the roof have been removed, and the roof has fallen in, immense cavities are made, which serve as inverted gas-holders, and contain many thousand cubic feet of gas, which, being about six times lighter than common air, collects in the upper parts of the works. These reservoirs of gas, called by the miners "goafs," extend sometimes over a space of one hundred acres, and when filled with gas, a diminution of the pressure of the atmosphere causes it to expand, and fill the passages of the mine more quickly than the ordinary means of ventilation are adequate to remove, and then follow those explosions that so often prove destructive of human life.

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* It is estimated that 37,000,000 tons of coal are raised yearly in Great Britain, of the value at the pit's mouth of £10,000,000. The capital employed in the trade exceeds £10,000,000, and 120,000 persons are employed in the mines.

The accumulation of gas during the night makes it more dangerous to descend the pits in the morning, and the practice often adopted is, to send down a viewer with a safety lamp to examine the more inflammable parts of the mine, before the men are allowed to go to work. This precaution is, however, not carefully attended to; and in one fatal instance of recent occurrence several miners accompanied the viewer with unprotected candles, and they were all killed by the explosion of the gas. It has been suggested by the author, as a means of testing the condition of a coal mine more effectually, that lucifer matches should be ignited in the dangerous parts by voltaic agency, before any one was allowed to descend the pit.* This would afford one means of avoiding the accidents that so frequently occur to the miners by their own folly and recklessness.†

The seams of ironstone that accompany coal strata constitute very valuable parts of many coal fields. When the ironstone is of good quality, it yields as much as thirty per cent. of the metal. About six tons of coal are required to produce one ton of iron, therefore the intimate association of the two minerals is of great importance to the cheap production of the most useful of all the metals. It is a remarkable circumstance, that though seams of iron occur abundantly with the coal, and are deposited like other strata, scarcely any metallic veins are found above the mountain limestone.

CHAPTER VI.

LOWER SECONDARY STRATA.

Changes after the coal period.—Heterogeneous character of the strata deposited on the coal measures.—Lower and upper new red sandstones.—Foot-prints on sandstones.—Scarcity of fossils in these strata.—First appearance of reptilian remains.—Red marl, and its accompanying rocksalt, and brine springs.—Speculations respecting the origin of rock-salt.—Gypsum.—Magnesian limestone: its distinctive characters and fossils.

After the deposition of the coal measures, the crust of the earth seems to have been subjected to great convulsions, which disturbed the strata, and lifted them from their original horizontal layers into highly inclined and sometimes vertical positions. After these convulsions, which broke up the rocks on the surface, there appears to have been a long period of rest, during which the fragments of the upturned strata were mingled under water with the gradually deposited débris carried down from the hills and mountains, and spread over the tops of the uplifted coal strata. The result of such processes of formation, in which the circumstances must have differed according to the extent of the previous displacements of the strata, the height of the land, the character of the rocks brought to the surface, and the action of water, would of course be extremely various; yet they would bear a general impress of having been formed under similar conditions. This is exactly the case with the strata deposited over the coal measures.

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* Electric Science, p. 192.

† At the meeting of the British Association, at Cambridge, Professor Faraday mentioned his own experience of the recklessness of the miners. He and Sir Charles Lyell were commissioned by the government to inspect one of the coal mines near Sunderland, in which there had been a most destructive explosion. He was sitting down with a lighted candle in his hand, looking at the men preparing to blast a rock, and on inquiring in what place of safety their gunpowder was kept, he was startled by the information that he was sitting upon the barral containing it.

The heterogeneous and opposite structures of these composite beds, combined with a characteristic similarity, are thus described by Professor Phillips: "In the composition of this group we find traces of all the various operations of the sea. Limestone, crystallized, compact, brechiated, conglomerated, and earthy; full of magnesia, or containing carbonate of lime with little or no admixture. Locally rich in organic remains, but generally devoid of them; sometimes coloured red, blue, or white, in stripes and spots; fine grained, coarse grained, or full of innumerable pebbles derived from the primary and secondary rocks. Clays and marls of many various hues; both the sandstones and clays locally productive of remains of saurians, shells, and plants, but over long tracts wholly destitute of them. These organic remains are probably analogous to those of the carboniferous system, and partly to those which occur in the more recent oolites; and the whole formation, though so peculiar in character as to be readily and, indeed, unavoidably separated from both those systems, offers, by many resemblances, a natural transition from one to the other."*

These diversified strata of sandstones, clays, and limestones, lie unconformably on the coal measures, from which, therefore, they may be distinguished as a separate formation. In England there are two beds of new red sandstone, generally separated by a thick bed of magnesian limestone; but the two sandstones have so many features in common, and they occasionally pass into one another so completely, that they may be regarded as the same. On the continent, the upper new red sandstone and the strata associated with it are more distinctly separated than in this country, and from their divisibility into three, they have been called the "trias" or triple group. Some English geologists introduce a "triassic system" in their arrangements of rock formations, in which, however, the muschelkalk, that forms the third member of the series, is absent. Other geologists distinguish the upper group of the new red sandstone formation, in consequence of its containing deposits of salt, as the "saliferous system;" but we have thought it most consistent with the observed general characters of the rocks, their relative positions, and their associations with each other, to class all the strata that lie between the coal measures and the upper limestones as the Lower Secondary Formation. In this arrangement the "Permian system," which consists of the lowest new red sandstone and the overlying magnesian limestone, is amalgamated with the

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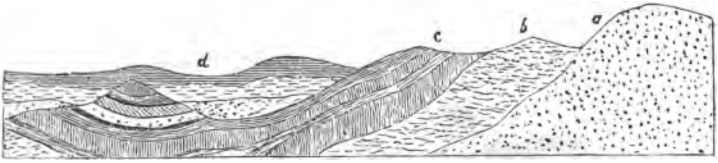
* Encyclopædia Metropolitana, article Geology.

"triassic system" of some geologists, the latter being composed of the upper new red sandstone, the muschelkalk (which does not occur in England), and the red marl.

The appearance and composition of the new red sandstones often closely resemble those of the old red sandstones that form the foundation of the coal measures; and in places where the coal does not intervene, the two seem to pass into one another. In England, the thickness of the lowest bed of new red sandstone is estimated at 600 feet, and that of the upper beds at 1000, making a total thickness of about 1600 feet. These sandstones occupy an extensive district in the Midland part of England, reaching from the east of Yorkshire into Dorsetshire, and on the west, from Cumberland to Devonshire; but, in parts, they are disconnected, and of small breadth. In Nottinghamshire and in Cheshire the new red sandstones are well developed. In the town of Nottingham many of the old houses have cellars cut into the rock, to the depth of more than thirty feet, with no other roof than the sandstone, and perfectly dry. In the ancient city of Chester, the main streets are cut through the sandstone, and the shops on each side are excavated in it.

The section (fig. 19) represents the succession of strata, and their general positions from the old red sandstone formation, *a*, on which the carboniferous limestone, *b*, rests; over it are the strata of the coal measures, *c*, and overlying the latter, unconformably, are the new red sandstones and their accompanying beds, *d*.

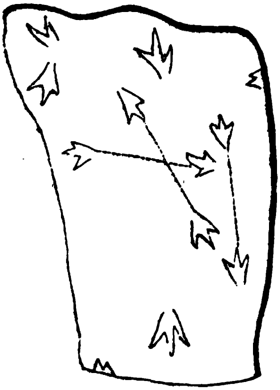
fig. 19.



Though the new red sandstone is generally destitute of organic remains, yet it contains traces of the inhabitants of former worlds, perhaps more interesting than those of fossil bones. It abounds with impressions of the feet of animals which once walked on the sea-shores when covered with the mud and sand that now constitute extensive tracts of inland country. The ripple marks of the sea on the shore-are very frequently preserved, and even the impressions of rain-drops may sometimes be seen—the relics of passing showers that fell on the surface of by-gone worlds. These impressions on the sandstone occur in layers, as successive accumulations of sand and mud have been deposited, and prove, most indisputably, that the rocks which now constitute considerable hills were formed on the sea-shore, and have been subsequently elevated.

In these fossilized footsteps we see the actual imprints of the feet of the animals as they lived, and not merely the remains of their bones. In the states of Massachusetts and Connecticut in North America, where the new red sandstone occupies a space 150 miles long and from ten to fifteen miles broad, there have been discovered impressions of the feet of thirty-two species of bipeds and of twelve species of quadrupeds. From the immense size of some of these footprints, it appears that birds living at that period must have been much larger than any now existing. Some of the footprints of birds are four times larger than the foot of an ostrich, and equal in size those of the dinornis, a gigantic bird, which, at no distant period, lived in Australia.

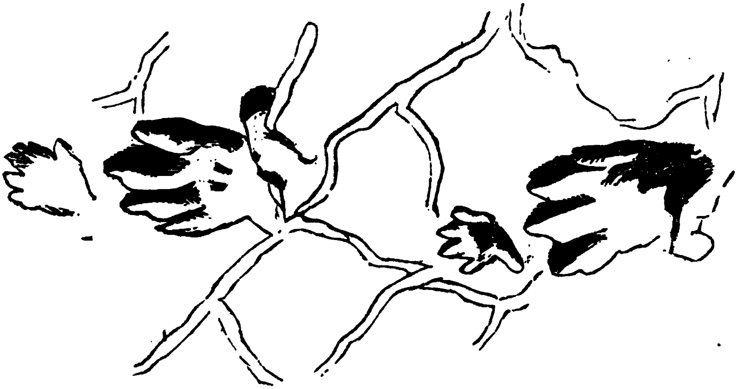
fig. 20.



The footprints of birds and quadrupeds found in the new red sandstone occur in regular tracks, showing the courses they took when walking on the shore, and the distances apart indicate the lengths of their respective strides. Fig. 20 represents the impressions of the feet of extinct birds as found in the new red sandstone of the Valley of the Connecticut, North America.

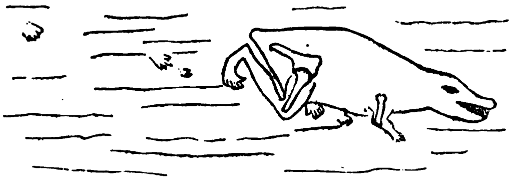
The most remarkable impressions of four-footed creatures preserved in the new red sandstone are those of prodigious frogs, some of the prints of the hind feet being eight inches long and five inches broad; and of the fore feet, four inches by three. Impressions of the fore and hind feet occur two inches apart, and the separation of each pair of footsteps is fourteen inches. The accompanying woodcut (fig. 21) shows the forms of the fore and hind feet and their relative sizes.

fig. 21.



Professor Owen, who has distinguished himself by his interesting revelations of the characters and habits of the animals that formerly lived on the world, derived from a careful examination of, and scientific induction from, their fossilized remains, was the first to ascertain that those footsteps were made by creatures of the order of frogs (batrachians). From the depth of the impressions, it was inferred, in the first place, that they must have been made by animals not walking under water; and by examination of the structure of some of the fossils that were discovered, the order of animals to which the creature belonged was ascertained. The teeth exhibit a remarkably involved arrangement, resembling that of the brain; and from this peculiar labyrinthian structure of the teeth, Professor Owen gave this monster frog the name of labyrinthodon. Some of the teeth discovered are three inches and a half long and one inch and a half broad. From examination of the prints, and from the few fossil remains that have been found, Professor Owen has been enabled to "restore" the whole animal in its pristine form, of which the accompanying woodcut is a representation, on a diminished scale.

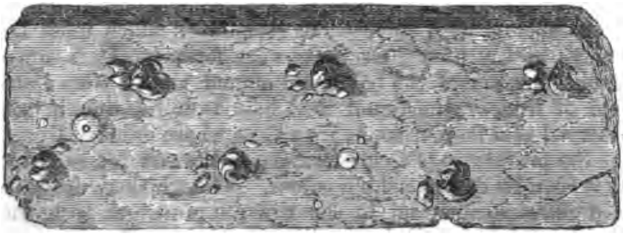
fig. 22.



The preservation of the footprints in an indurated state is accounted for by supposing that the impressions were made in tenacious mud or soft clay, and that the indentations were shortly afterwards filled with sand. The sand thus introduced and subsequently hardened has produced casts of the original impressions, and successive layers occur of footprints with their casts in sandstone fitting into them. Thus the inhabitants of former worlds, as they trod along the shore, unconsciously formed matrices for casts in solid rocks that serve as everlasting monuments of their existence.*

Numerous footprints have been found on the new red sandstone of Warwickshire, Shropshire, and Cheshire, and they are particularly conspicuous in the patches of that rock which occur in the valleys of Nith and Annan, in Dumfriesshire. In Corncockle Muir quarry, in Annandale, on the estate of Sir William Jardine, the sandstone abounds in footprints of various kinds; and the working of the quarry having been for several years in the hands of Sir W. Jardine himself, who has taken great interest in these records of former existences, it has afforded opportunities not previously possessed of preserving whatever was recovered. A series of magnificent illustrations of these fossil footprints is presented in "The Ichnology of Annandale," from which publication we copy the accompanying representation, on a reduced scale, of the "chelichnus ambiguus."

fig. 23.



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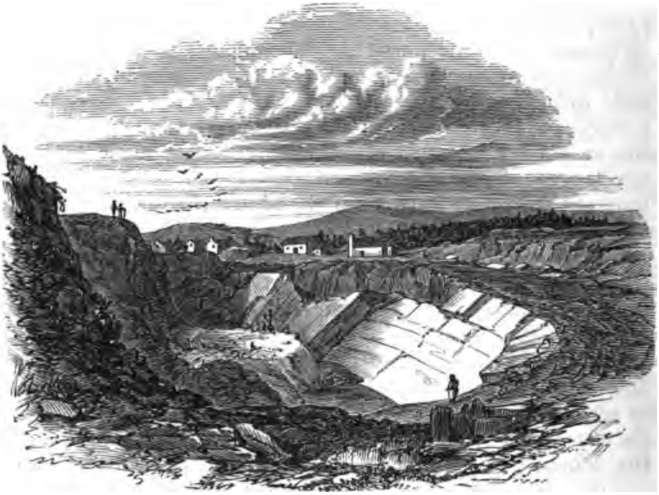
* Large slabs of sandstone, with these impressions and the natural casts taken from them, exhibiting exact forms of the feet, are to be seen in the mineralogical collection of the British Museum.

Corncockle Muir is an elevated ridge about a mile in length, situated near the centre of the valley. The total thickness of the beds of stone worked in the quarry is about two hundred feet. Their dip is nearly east to west, inclined at an angle of from 34° to 37°. Sometimes they are merely separated by very thin layers of unctuous clay; and it is upon these that the impressions are best preserved—the cast and its mould separating easily from each other. It is a curious fact, that nearly all the footprints are impressed as if the animals had walked from west to east, or from where the water is presumed to have been towards the land. This appearance, Sir W. Jardine observes, "may have proceeded from the softer state of the sand at the ebb of a tide causing the tracks entering or approaching the water to have been obliterated; while the returning tracks, being impressed on partially dried sand, have been preserved." The accompanying representation of Corncockle Muir quarry, showing the position and inclination of the beds of new red sandstone, is reduced from the vignette frontispiece of Sir W. Jardine's work.

fig. 24.



It is a remarkable fact, that few organic remains are found in the strata that abound with impressions of animals which must have lived on the earth at the time these rocks were formed. It is supposed that the organic structure of the bones and animal matter were destroyed by the oxide of iron, or the liquid that held it in solution, it being generally observed that fossil remains are absent where oxide of iron abounds; and it is the prevalence of that substance in the new red sandstone which gives that rock its distinguishing colour. Though there are scarcely any organized remains, however, in the new red sandstone rock, the exuviæ of animals are found, called coprolites; and from the chemical analysis of these remains, supposed to be those of birds, it has been ascertained that the animals from which they dropped lived upon fishes.

No general character can be given to the new red sandstone that is not liable to exceptions, owing to the variable circumstances under which it was deposited; therefore, though, generally speaking, it is devoid of organic remains, it is, in a few districts, and to a limited extent, very fossiliferous. In the neighbourhood of Axmouth, in Devonshire, and of Westbury, in Somersetshire, there are patches of strata, called bone beds, that contain many organic remains, among which are those of lizards (saurians) and fishes. With the exception of a species of lizard that has been found occasionally in the coal measures, the fossil remains of those reptiles in the upper beds of the new red sandstone are the first indications of their existence on the earth.

The upper new red sandstone is covered with a stratum of red marl, which forms a stiff loam, and produces a very fertile soil. These beds of marl are in some parts of England six hundred feet thick; and in Germany, where they form the upper beds of the trias group, they attain the thickness of one thousand feet. The red marl accompanies the new red sandstone generally through the range of country previously indicated, and it is chiefly remarkable for containing beds of rock salt and gypsum.

The rock salt is limited in England to Cheshire and Worcestershire. Droitwich is the centre of the rock-salt district of Worcestershire; but there the rock is not worked into, the salt being procured by evaporation from springs of strong brine, which yields about one-third its weight of salt. Salt springs occur also in many other places along the range of the upper new red sandstone; and from this circumstance, as before noticed, geologists sometimes distinguish the upper strata of this formation as the "saliferous system."

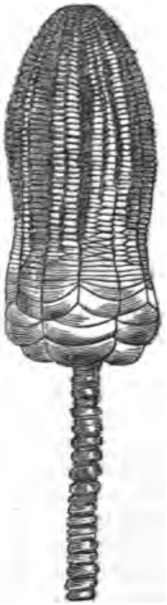
Hungary and Poland contain the most numerous and extensive repositories of salt in Europe. Some of these beds have been worked for salt at a depth of nine hundred feet.

There has been much speculation exercised in endeavouring to account for the deposits of salt. The most feasible opinion seems to be that salt was deposited by the evaporation from salt-water lakes. It is conjectured that extensive tracts of land, below the level of the sea, might have been separated from it by bars of mud or sand, and being often inundated during high tides, its evaporation would be continually going on, the water would become super-saturated, and the salt be deposited. The Dead Sea, and some salt lakes in Caffraria, that have thick deposits of rock salt in their beds, and other salt-water lakes, are adduced as confirmatory of the supposition that the beds of salt were thus derived from the ocean.

Gypsum (sulphate of lime), the mineral associated with rock salt in the upper beds of the new red sandstone, has been already noticed among the materials of rocks (page 17). It occurs in the new red sandstone formation in England in detached beds, as a local deposit; but in the Alps, it assumes greater importance, and comprises beds of rock that are regularly stratified.

The magnesian limestone, which intervenes between the lower and upper new red sandstones, is distinguished from the magnesian limestone that occurs among primary rocks by its colour and the varieties of its structure, though not by its chemical composition. They both contain nearly equal parts of carbonate of lime and carbonate of magnesia, generally with a preponderance of the former. The magnesian limestone associated with primary rocks is either white or light grey, but the magnesian limestone of the new red sandstone is of a dark brown or yellowish brown colour; and its structure varies from granular and laminated to crystalline. The harder kinds form very durable building stone, for which purpose it is extensively used in the north of England. Magnesian limestone extends from Newcastle to Nottingham, varying in thickness from 400 feet, near Sunderland, where it is best developed, to a few inches. It does not occur continuously much farther south than Nottingham; beyond which point it is met with only in detached beds of small extent and thickness.

fig. 25.



The beds of magnesian limestone occasionally contain small veins of copper and other metallic ores, which, on the Continent, where this formation is much more largely developed than in this country, are occasionally sufficiently thick and rich to be profitably worked. On passing down, however, to the underlying red sandstone, these metallic veins cease to be productive; hence the German miners have given to the lower beds of new red sandstone the name of rothe-todte-liegende, or red-dead-layers, signifying that they are dead or unprofitable strata; and this barbarous name is frequently used by English geologists.

The muschelkalk, which occurs in Germany between the lower and upper new red sandstone, but has no exact representative in this country, is upwards of 600 feet thick. It consists of a series of calcareous strata, and contains remains of reptiles similar to those found in the beds of lias limestone, which constitute the lowest of the middle secondary formation, to be described in the next chapter. One fossil peculiar to the muschelkalk is the lily encrinite figured in the annexed woodcut.

CHAPTER VII.

MIDDLE SECONDARY STRATA.

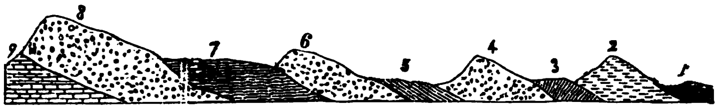
Geological and geographical positions of this group of strata.—Lias limestone.—Burning cliff at Lyme.—Abundance of reptilian fossils in lias.—Oolitic beds.—Succession of beds resting upon the lias.—Peculiar fossils in the Stonesfield clay.—Remains of carniverous molluscs in oolite.—Elevation of oolitic rocks.—Differences in character of oolites.—Middle and upper groups—Portland stone: its defects as building material.—Absence of coralline fossils.—Speculations on the formation of lias and oolite.

THE group of strata which, in the arrangement we have adopted, constitutes the middle secondary formation, comprises all those that lie between the upper new red marl and sandstone, and the freshwater formation called the Wealden group, which is interposed between this middle series and the strata immediately associated with the chalk.

These beds form an important feature in the geology of England. They come to the surface from Dorsetshire to the eastern part of Yorkshire, and occupy a broad and elevated tract varying in breadth from 10 to 100 miles, being distinguished by geologists as the oolite system. The most important members of the group are the lowest beds, resting on the red marl, and consisting of a peculiar blue limestone called lias. This name is supposed to be derived from a provincial pronunciation of the word "layers," and, barbarous as it is, it may claim to be a more correctly distinguishing term than most of the names given to rocks; for the stratification of this limestone is peculiarly even, and looks like an arrangement of broad bands lying one above the other.

The annexed section across the country, from London to Cheltenham, will convey an idea of the positions of this group of strata in relation to those above them; but in this, as in all other sections of extensive districts, the elevations are greatly disproportioned to the width of the beds.

fig. 26.



1. London clay; 2. Chalk; 3. Gault; 4. Upper oolite; 5. Kimmeridge clay; 6. Middle oolite; 7. Oxford clay; 8. Inferior oolite; 9. Lias.

When the lias beds are fully developed, with their associated beds of clay, they form a stratified mass of nearly 1000 feet thick. The regularly stratified lias limestone occupies the lower part, and the lias clay the upper. The quality of the limestone varies considerably, and also its colour; the upper beds being much finer grained than those beneath, and when ground smooth forms slabs fit for lithographic printing. The chemical constituents of the purest beds are carbonate of lime, in the proportion of 80 or 90 per cent., combined with alumine, iron, bitumen, and sulphates of soda and magnesia. Some of the beds of lias are slaty, and contain iron pyrites—a compound of iron with sulphuric acid. The pyrites is decomposed when in contact with water, and the heat generated is sufficient to ignite the bitumen spontaneously. It was by spontaneous ignition of this kind that the curious phenomenon of the burning cliff at Lyme, in Dorsetshire, was produced, and not by volcanic agency.

The saurian or lizard tribe, of which there are abundant remains, are the most extraordinary of the fossils found in the lias limestone. Some of these creatures must have been from thirty to forty feet long; and from the forms of their teeth, it is ascertained that they were predatory and fed on fish, living with them in the sea or in estuaries of rivers. The means that some of them were provided with for pursuing and capturing their prey, must have rendered them formidable enemies even to the sharks, which lived at the same period. One of these creatures, the icthyosaurus or fish lizard, had a head resembling that of a dolphin, rows of large conical teeth, and prodigiously large eyes; the orbits of the eyes

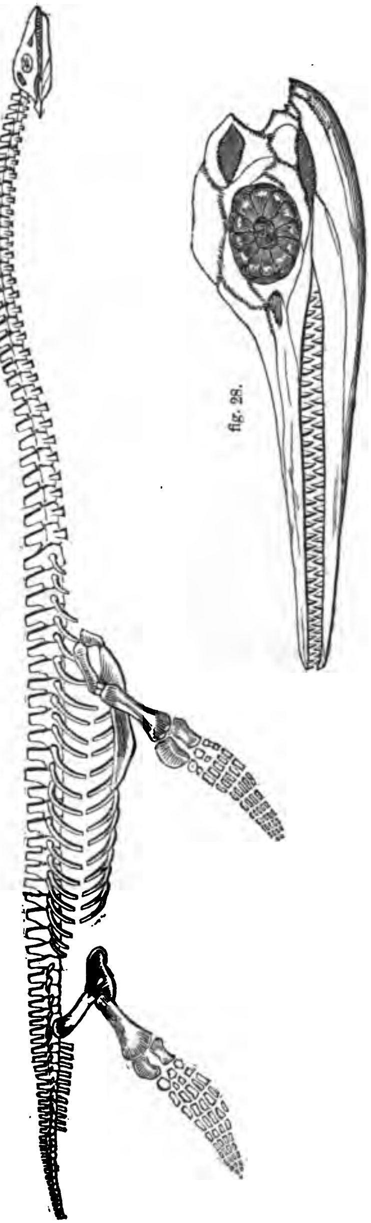


fig. 29.

fig. 28.

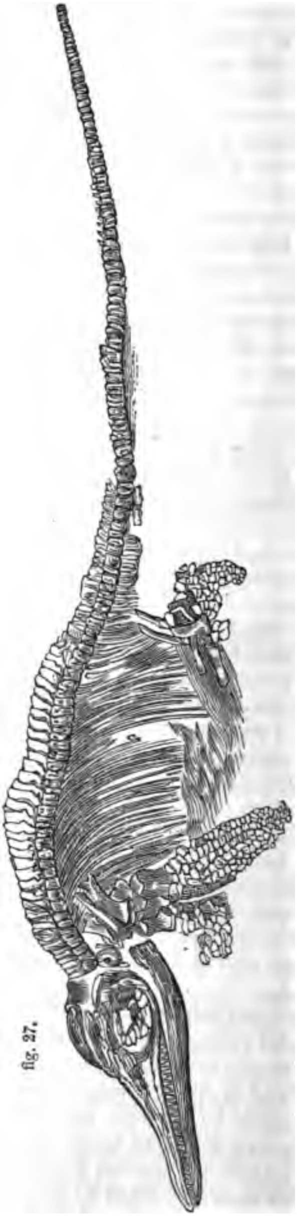
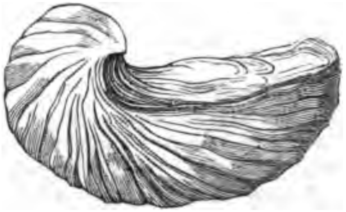


fig. 27.

in some of the specimens found being one foot long and ten inches wide. The vertebræ of the ichthyosaurus were so formed as to enable it to move its tail with great facility, being deeply concave like those of the shark; and with this facility of movement, aided by the propelling power of four large paddles, it must have moved through the water with great rapidity. It may be assumed, from the size of the eyes, that the ichthyosaurus lived in turbid water, the organs of sight being adapted to receive a sufficient number of the rays of light to compensate for their feeble illuminating power.

The drawing (fig 27) represents the skeleton of the ichthyosaurus as found in the lias by the Rev. Mr. Conybeare, who paid great attention to the elucidation of the fossils of the lias strata. Fig. 28 is the head of a restored specimen. To the same gentleman geologists are also indebted for the first restoration of the skeleton of another very remarkable animal of the lizard tribe called the plesiosaurus, represented in fig. 29 above, the ichthyosaurus. The peculiar characteristic of the plesiosaurus was the great length of the neck, which was longer than the body, and was composed of thirty vertebræ of a less concave form than those of the fish lizard Some of the plesiosauri must have been twenty feet long.

fig. 30.



Among the shells found in the lias is a graphite, bivalve, which is so characteristic from its abundance, that French geologists call the lias limestone *calcaire à gryphites*. Another fossil abundant in the lias is the pentacrinite, a zoophite, with long branching arms and articulated stem, resembling a vegetable product. The chief difference between pentacrinites and the encrientes, of which there are such abundant remains in the carboniferous limestone, consists in the form of the stem; that of the pentacrinite, as its name imparts, being pentagonal, whilst that of the encrinite is round.

Above the lias occurs the regular oolite formation, which consists of a great variety of beds of pale yellow limestone, alternating with beds of clay, marl, sand, and calcareous sandstone, attaining a total thickness of 1200 feet. The principal member of this group, and from which it derives its name, is a sandy limestone, composed of round particles imbedded in a cement of limestone, looking like the roe of a fish, and hence locally called roe-stone, which, disguised in Greek, becomes the oolite of geologists.

The oolite formation is divided into the lower, middle, and upper, by thick beds of clay. These may be considered as distinctive lines, which separate a series of strata otherwise very closely allied. In the division and description of these strata we shall adhere, for the most part, to the arrangement in the "Introduction to Geology." The lower oolites are divided from the lias limestone by a thick bed of calcareous clay, called lias clay, and by an upper seam of ferruginous marl. The order in which the strata then succeed, commencing with those that rest on the lias clay and ascending towards the upper beds, is as follows:—

1. Inferior oolite (Cheltenham).
2. Fullers' earth.
3. Stonesfield slate.
4. Great oolite (Bath).
5. Beds of clay, sand, and grit.
6. Forest marble.
7. Cornbrash.

1. The inferior oolite differs little from the great oolite above it. In the south-west of Gloucestershire, it consists of nearly equal divisions of soft oolite limestone and calcareous sand, arranged in different beds; but in no instance does this oolite attain the hard quality of the best building stone of the great oolite formation near Bath. The thickness of these beds in Somersetshire is 130 feet.

2. The bed of clay called fullers' earth, resting upon the inferior oolite in Somersetshire and Gloucestershire, may be considered merely local, for it does not extend northwards beyond the latter county. In the neighbourhood of Bath, however, it is estimated to be 150 feet thick. Fullers' earth consists principally of silica, alumina, and oxide of iron, the silica forming 53 parts per cent., and the alumina and iron about five per cent. each.

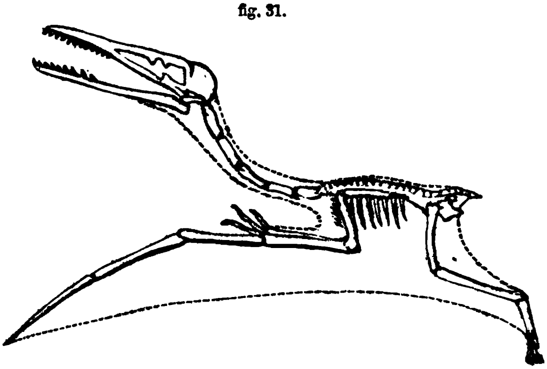
3. The Stonesfield slate is a slaty limestone resembling lias, remarkable for the organic remains found in it at Stonesfield, near Blenheim. Like the bed of fullers' earth beneath, it may be considered as a limited local deposit; and were it not for the remarkable fossils it contains, would be scarcely worth notice as a geological formation. The Stonesfield slate consists of two beds, each about two feet thick, and separated by a bed of calcareous sandstone of similar thickness. On exposure to frost, it splits into thin plates, which are used for roofing.

Among the abundant fossil remains of the Stonesfield slate, the most remarkable are those of the lower jaw bones of animals, which Professor Owen has determined belong to the genus of marsupians, or opposums. The occurrence of mammaliferous animals in the secondary strata was previously unknown; and they are not found in any other strata till we arrive at a much more recent geological period. All the specimens yet discovered amount only to the fragments of seven lower jaw bones; yet from these few remains, Professor Owen has determined, with great certainty, the character and habits of the animals to which they belonged.

Among the other interesting remains found in the Stonesfield slate are impressions of the outer cases of winged insects, bones of the megalosaurus, a gigantic lizard, and of a remarkable animal called pterodactyle or flying lizard, which varied in size from that of a snipe to that of a cormorant. Dr. Buckland determined that these creatures resembled bats in general form, but with the elongated heads of lizards. Their eyes were of enormous size, to enable them to see in the night time, and their teeth were sharp and conical. A representation of the skeleton of one of these creatures restored is shown in figure 31.

The preservation of the wing-cases of insects in the Stonesfield slate indicates a very tranquil condition of the earth at the period of deposition; and these insects, in conjunction with the pterodactyles and opposums, also point to the neighbourhood of dry land, though most of the other fossils that occur in the oolite formation are those of marine animals.

fig. 31.



4. The great oolite is the most perfect oolitic rock of the series, and is the best developed. In the neighbourhood of Bath, it is 150 feet thick; but not in a bed of uniform quality. It consists, like the other divisions of the group, of a variety of beds of different degrees of hardness, in which comminuted shells are mingled with the oolite limestone. The upper and lower beds, which are coarser and more shelly, are called rag stones. The best building stone, when quarried from the rock, contains a quantity of water, and is very soft; but after it has been exposed to the atmosphere, it hardens and forms excellent building material, the property of softness when first extracted greatly facilitating its being cut into blocks and carved.

In the great oolite there have been found 142 species of shells, of which number forty-one have been ascertained to belong to carnivorous molluscs. This is so far remarkable that, like the occurrence of fossil remains of opposums in the Stonesfield slate, it throws light on the existence of that genus at a period long before they were supposed to have appeared on the earth. Until these carnivorous molluscs were detected in the oolite, they had not been found, in any numbers, till after the chalk formation.

5. The beds called forest marble, in the lower oolite series, consist of clay, sand and grit, and coarse oolite; the lowest bed being of clay fifty feet thick, to which the name of Bradford clay has been given; and the uppermost bed being also of clay, but considerably thinner. The coarse oolite occupies the central part of the series. The thickness of all these beds in Somersetshire is 150 feet.

6. The local name of Cornbrash has been retained for a bed of rubly hard limestone, generally detached in masses, and of little geological importance, excepting for its abundant remains of organic life. It forms a very fertile soil, to which character it is indebted for its name; and Mr. Smith, the first English geologist who industriously examined the geology of the south-western part of England, having adopted the local name of cornbrash, it has been generally so called.

Of the preceding series, the inferior oolite constitutes by far the most important stratum. It extends in a north-easterly direction through England, from Dorsetshire to the Cleveland Hills in Yorkshire, throughout a range of lofty hills, which, in the neighbourhood of Cheltenham, attain the height of 1100 feet, and near Ingleby, in Yorkshire, 1500 feet; but the general elevation is from 600 to 800 feet. No beds of oolite are found to the north-west of the Severn. They occur in Sutherlandshire and in the western islands of Scotland, and, as before stated, in France, and in the Jura Alps; but the oolitic series is wanting in Russia and in North America.

It must be observed that the series of beds in the lower oolite differ considerably in various parts of England; so much so, indeed, that, looking at the rocks separately and without regard to the accompanying strata and fossils, it would often be difficult to determine that they belonged to the oolitic system. In Yorkshire, for example, there are thick depositions of sandstone, shale, and coal below the cornbrash, which is there diminished to a stratum of five feet thick, whilst the distinguishing feature of the system, the roe-stone, can be scarcely recognised in a bed of impure limestone that is supposed to represent it. The geological positions of strata associated with known rocks and corresponding fossils are, however, considered sufficiently characteristic to class them in the same formation.

A marked distinction has also been observed in the constituents of oolitic rocks as they extend northward. In Yorkshire, the oolite is more sandy than in Somersetshire, whilst in the Alps the calcareous strata further increase, and the sand and clay are diminished.

The most marked feature of distinction between the lower oolite group and the upper is the broad line of separation by a bed of clay, called the Oxford clay, which, in Somersetshire, is 300 feet thick, and extends into Yorkshire as a division line of half that thickness. Some of the beds in the Oxford clay are bituminous and nearly resemble lias clay, and other beds are much intermixed with calcareous earth; for though the name Oxford clay applies to the whole bed, it is composed of a variety of argillaceous strata.

The principal strata in the middle oolite consist of calcareous sand and clay, coral rag, and calcareous freestone, which pass into each other and vary much in thickness. The coral rag contains in some parts remains of madrepores and coral polypi; the calcareous freestone consists of comminuted fragments of shells in limestone more or less oolitic. The rounded particles sometimes become as large as peas; and this variety of roe-stone has, therefore, received the name of pisolite, or pea-stone. The thickness of the middle oolite, including the Oxford clay, is about 400 feet.

The middle oolite is separated from the upper by a thick bed of clay, called Kimmeridge clay, from Kimmeridge in Dorsetshire, where it attains a thickness of 200 feet; but it thins out on proceeding northwards, and does not occur in the oolite system of Yorkshire. Kimmeridge clay is of a grey colour, and passes into a shale, which is sometimes so bituminous as to be used for fuel.

Resting on the Kimmeridge clay is the Portland sand. It is calcareous, and contains green particles like those which give a distinguishing character to the important formation of green sandstone that occurs in the upper strata, to be afterwards noticed. This bed of sand in the Isle of Portland, from which it derives its name, attains the thickness of 80 feet. It passes gradually into the Kimmeridge clay beneath, and into the Portland stone above. The latter is a sandstone mixed with calcareous particles, and is well known from its having been used extensively as a building stone in London, where St. Paul's Cathedral and Somerset House present magnificent specimens of the rock. The thickness of the bed is 70 feet, but it is of very limited extent. The good colour and fine structure of Portland stone well adapt it for ornamental buildings; but it does not possess sufficient hardness for structures exposed to the action of water. Blackfriars Bridge, which was built of this material, has long since been in a state of decay, and is a costly proof of the unfitness of Portland stone for bridges. The effect of rain and frost on the surface of this stone is also observable on several of the public buildings in London. The depositions of soot on the surface, have in places been cleared away by the crumbling of the stone, and a fresh clean surface has thus been exposed, which contrasts strongly with those parts that still retain their sooty covering.

CHAPTER VIII.

UPPER SECONDARY STRATA.

The Wealden strata: their geological position and limited extent. — Changes indicated in the condition of the globe.—The Portland dirt beds.—Composition of the Wealden group and fossils.—The chalk system.—The green-sand.—Variations in its structure in different localities.—Chalk: its distinguishing characteristics.—Absence of usually accompanying strata.—Distinguishing characteristics when separated.—Geographical distribution.—Organic remains in chalk.—Indications of formation at the bottom of the sea.

The upper secondary formation comprises the chalk, the most distinguishing geological rock, and its accompanying beds of green-sand. These beds are, however, locally separated from the lower secondary rocks by several remarkable freshwater deposits called the Wealden group, which, though occurring only in the south-eastern part of England, and scarcely to be recognised elsewhere, possess perhaps as much geological interest as any other group of strata. The Wealden beds cover most of the wealds of Sussex and Kent, and extend in patches into Dorsetshire to the west, and may be traced into Buckinghamshire to the north-west. In Sussex and Kent they are surrounded by the chalk, excepting on the south-east, where they dip under the sea, and some traces of them reappear at Boulogne, and still more completely at Beauvais. The total thickness of the beds is estimated to be upwards of 800 feet.

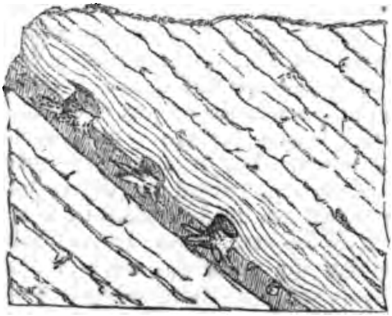
It was formerly supposed that the Wealden beds were deposited above the chalk which surrounds them, and that they belonged to the freshwater deposits of the tertiary period; but it is now well ascertained that they rise from under the green-sand, and rest upon the upper oolites.

The interest attached to these strata arises from the numerous evidences they afford of changes on the surface of the earth before, during, and after their formation. Though resting upon rocks that were deposited under the sea, they bear decisive marks of having been formed above its level, and they also indicate a subsequent submergence, whilst other strata, thousands of feet thick, were deposited upon them under the sea.

The Portland stone quarries present excellent sections of the junction of the marine strata with the freshwater beds above them. A stratum of calcareous marl, about two feet thick, rests immediately on the upper oolite, over which there occurs a stratum of dark argillaceous and carbonaceous matter about the thickness of six inches, which contains fossilized remains of trees resembling those of existing species of pines. The stumps of these trees are erect, and apparently in the situations in which they grew. Over this stratum of dark-coloured loam, called the "dirt bed," there is a stratum containing freshwater shells, and upon that there rests another dirt bed, thicker than the former, in which there are stems of trees six and seven feet high, with their roots attached, quite erect, and at such distances apart as are usual with trees in primeval forests. These trees belong to a species of pine, and occasionally, where they are found lying prostrate, they extend a length of twenty-five feet. This upper dirt bed is covered with a stratum of freshwater limestone.

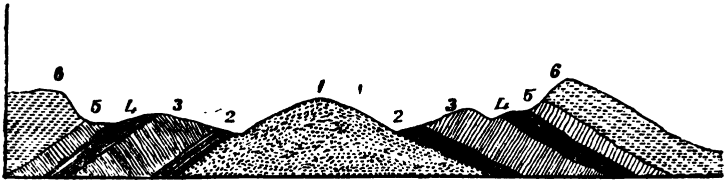
The dirt bed affords other evidence of the ancient condition of the earth. In the first place, the remains of the soil of which it is composed, shows that the destruction of vegetation and the submergence of the surface was not produced by any violent convulsion, or sudden inrush of water, for in that case the soft soil would have been swept away, and the trees uprooted. In the next place, we learn that the deposition of the upper strata must have been made in very tranquil water; for the successive layers lie conformably, as it were, to the upright stumps of the trees, forming waving lines above them. A still further illustration of the changes that took place on the earth's surface, is afforded by the position of these strata in a cliff at Lulworth Cove in Dorsetshire, of which fig. 32 represents a section. After the forest had been submerged, and the upper strata had been deposited upon it, the whole mass was lifted up and inclined at an angle of 45 degrees; but the trees, which of course grew perpendicularly, are slanted so as to form an equal angle in the opposite direction. A more conclusive proof of the elevation of the strata after deposition could not be afforded.

fig. 32.



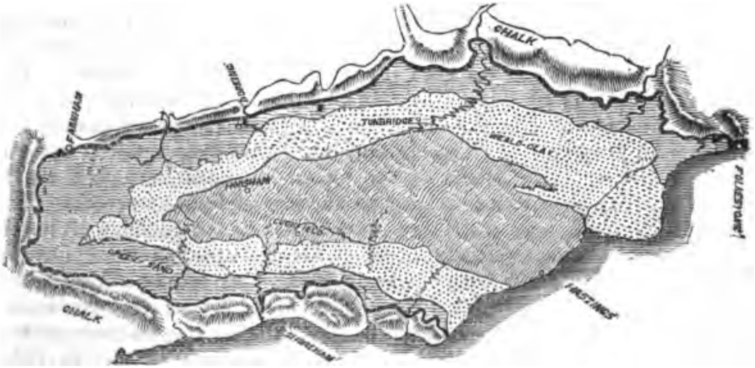
The regular Wealden group comprises what are called the Purbeck strata, the Weald clay, and the Hastings sands. The section fig. 33 shows the order of succession of these strata. The centre, 1, is occupied by the Hastings sands; 2, 2, Weald clay; 3, 3, lower green-sand; 4, 4, gault; 5, 5, upper green-sand; and 6, 6, chalk.

fig. 33.



The positions the Wealden strata occupy in Kent and Sussex, where they are principally developed, will be best understood by inspection of the accompanying map of the district.

fig. 34.



The Purbeck strata consist of a slaty limestone of a grey colour, argillaceous, and in some parts containing compact limestone. Within these strata is one, called by the quarrymen the cinder-bed, filled with oyster-shells, which seems to militate with the received opinion of the freshwater nature of these formations; but oysters are met with in the estuaries of large rivers, and in such situations it is probable the Wealden beds were deposited. The Weald clay is a blue or brown tenacious clay, sometimes indurated and slaty. Beds of limestone occur in different parts of the Weald clay, known as Sussex marble and Petworth marble, some of the varieties of which are sufficiently hard to bear a high polish. The Hastings sandstone is composed of whitish grains of sand slightly adhering, and alternating with beds of clay, and with a small conglomerate sandstone containing rounded fragments of bones and scales of fishes. Over this sandstone there occurs, in the Tilgate Forest, a bed of coarse conglomerate consisting of quartz pebbles and pieces of ironstone and jasper.

The whole of the Wealden formation is composed of beds of clay, limestone, and sandstone alternating with each other, in which clay predominates. In the central portion of the group, the sandstone is most prominent, extending from beyond Horsham to Hastings, and forming a range of hills of considerable height. Crowborough Beacon, the highest point, is upwards of 800 feet above the level of the sea.

Ironstone occurs in considerable quantities in the Hastings sandstone. In the sixteenth century, two-thirds of the iron manufactured in England was obtained from the Sussex beds. The Wealds of Kent and Sussex being then covered with forest-trees, supplied the fuel for smelting the ore.*

The organic remains of the Wealden beds are no less remarkable and interesting than the peculiar characteristics of the strata in which they are found. The fossil-trees indicate that the land was elevated above the surface of the sea, and that the vegetation upon it was the product of a tropical climate. Similar indications of dry land and of tropical plants are, indeed, exhibited in the strata of the coal measures; but at that period the earth does not appear to have been fitted for the maintenance of the life of terrestrial animals. From the organic remains in the Wealden beds, however, we learn not only that the surface of the earth was then adapted to the support of animal life, but that the creatures which fed upon the luxuriant vegetation, were monsters of gigantic size, with which no land animals now living can compare. The most extraordinary of them was the iguanodon, the fossilized bones of which were discovered by Dr. Mantell. Its form resembled that of the iguana, a large species of West Indian lizard that frequents the trees in the West Indies. The length of the iguanodon must have been nearly seventy feet, which is twice as long as the largest living crocodile. The forms of its teeth bear a striking resemblance to the grinders of herbivorous animals, being evidently intended for the mastication of food, in which respect they differ from the teeth of all other species of lizards.

The chalk and its associated sands have been termed the "cretaceous system," from *creta*, chalk. When fully developed, they consist of five principal beds. The lowest is a deposition of sand mixed with particles of silicate of iron, which give a green colour to the rock, and from that circumstance it is called "green-sand." Sometimes it occurs in beds of loose sand, as its name implies; but generally the siliceous particles are imbedded in an argillaceous and calcareous cement, and form a compact sandstone. The united thickness of the green-sand is about 400 feet.

The lower bed of the green-sand is separated from the upper bed by a broad stratum of stiff clay or marl called gault, about 250 feet thick; it is well developed at Folkestone beneath the chalk, and is consequently sometimes called Folkestone marl. The thickness of this bed of clay, however, varies very much, and it diminishes towards the north, in Yorkshire, to twenty feet; but whether thick or thin, this clay division between the upper and the lower green sand very constantly accompanies the two beds throughout their whole course.

The upper green sand is more calcareous than the lower, and near its junction with the chalk, it passes into a calcareous clay called chalk marl, which constitutes a distinct stratum in the cretaceous system.

Chalk is the most constant characteristic rock of any in the geological series. Its white appearance instantly distinguishes it from other minerals. The general earthy structure and comparative softness of chalk constitute an important difference between it and limestone, with which the constituents of chalk closely correspond, as it is composed entirely of carbonate of lime. But though chalk is so easily distinguishable from other minerals, it nevertheless varies greatly in its degrees of hardness, from a soft chalky marl to a hard white stone, the surface of which does not rub off like that of common chalk. The chalk in the north-east of Ireland is of this description. In a few places also the colour changes to red, owing to the presence of iron, a stratum of which kind occurs in Yorkshire.

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* Introduction to Geology.

The thickness of the chalk beds in the south of England is estimated to be from 600 to 800 feet. The upper bed is distinguished from the lower by containing nodules of flints, arranged in layers, which do not occur in the lower chalk.

The five separated beds that compose the chalk formation—the lower green-sand, the gault, the upper green-sand, the chalk marl, and the chalk—diminish in number as they extend towards the north, where the sandy portion of the group increases, and the gault and chalk decreases; and even the beds of green-sand that occur in Yorkshire contain fewer calcareous particles than the corresponding beds in Sussex.

There is a local deposition of calcareous marl above the chalk, which from the circumstance of its occurring conspicuously on the top of St. Peter's hill, near Maestricht, has been called the Maestricht bed. This is also classed with the chalk formations, but in many of its characters it assimilates to the freshwater tertiary strata lying above.

Chalk does not occur in England farther north than Yorkshire; it passes through Lincolnshire, Norfolk, Suffolk, Hertfordshire, Bedfordshire, Buckinghamshire, Oxfordshire, Wiltshire, and Dorsetshire; and thence extending eastward, it appears in the southern part of the Isle of Wight, and expands itself in Sussex and Kent.

In tracing any geological formation in different parts of the world, it is frequently observed that some members of the series, especially those that form the uppermost beds, are wanting, as if they had been swept away by the action of water. The lower beds of the carboniferous system, for instance, are often found without the overlying coal; and so also the green-sand beds occur at great distances apart without the chalk. As the external characters and structures of sandstones and their associated strata preserve no distinctive features, it might be supposed impossible to ascertain to what particular formation the beds of sandstone found in different parts of the world belong, especially when the principal member of the series is absent. With respect to the green-sand, this difficulty is increased, because the fossils in what is called the green sand in America vary greatly from those of the green-sand in Sussex. Out of 180 species of fossils that have been met with in the green-sand of America, only two are identical with those of Europe; but though there is not an actual identity of species, there is a prevailing analogy in the character of the fossils that is considered sufficient to identify the two formations. The shells of certain species of gryphæ, belemnites, and ammonites occur in both, which indicate that they were alike of marine origin, and similar shells are not met with in any strata deposited after the chalk. Thus, though only two species of the shells are exactly alike, when it is found that the sandstone of the two continents which occupy the same relative positions among other rocks contain distinct indications of having been deposited under the sea, and some corresponding fossils, they are considered to have been deposited at the same geological period; though local circumstances, such as different depths under water and different climates, may have occasioned differences in the characters of the submarine inhabitants living at such distances apart. Even within a much more limited range, and where the green-sand can be distinctly traced associated with chalk, the fossil remains exhibit great variations, as can be clearly perceived on comparing the fossils of the same beds in Yorkshire and in Sussex.

The organic remains in chalk indicate that it was deposited under the sea and in deep water, considerably removed from any land. The fossils are exclusively marine; and though fragments of the bones of the monster lizards of the oolite period which frequented the shallow waters of estuaries, are occasionally found, they are very thinly scattered among the chalk, as if they had been carried out to sea, and not accumulated in heaps near the places where the creatures lived, as in the lias. The most characteristic shells of the chalk are echinites or sea-urchins (fig. 35) and the chambered cells called scaphites, hamites, turrilites (fig. 36), and baculites (fig. 37). Ammonites (fig. 38), belemnites (fig. 39), and nautili (fig. 40*) are also found; and, though they are not peculiar to the chalk, they serve to mark distinctly the boundary of marine formations, as they do not occur in the upper strata. There are numerous remains of zoophytes converted into flint, the nodules in the upper beds of chalk having generally a nucleus of spongy zoophyte. The shells are prin-

fig. 35.

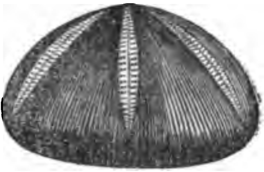


fig. 33.

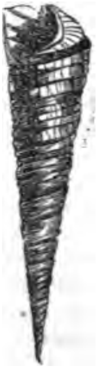
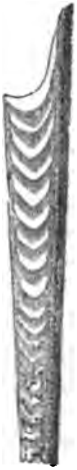


fig. 37.



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* The wood-cut represents a living nautilus, with the animal in the shell, the outer chamber of which alone it occupies; the other portions being divided into separate chambers, connected together by a small tube, by means of which it is supposed the nautilus can compress or rarefy the contained air, and thus sink or swim.

fig. 38.

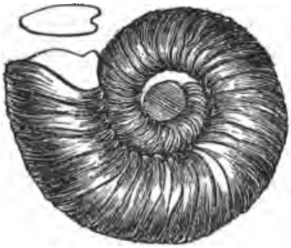


fig. 39.

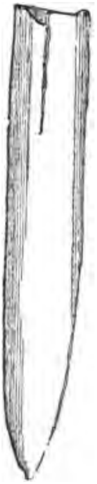
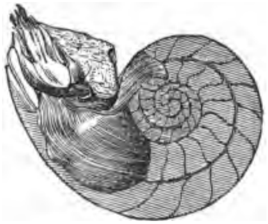


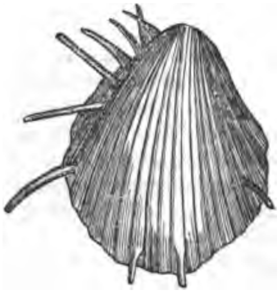
fig. 40.



cipally of the bivalve kind; the small number of univalve shells having been adduced to prove the depth of the sea, for as the inhabitants of such shells have eyes and stretch forth their heads in search of food, they would, it is conjectured, require more light for the purpose than could penetrate a mass of superincumbent water, and hence their limitation to a few species.

The fossils in the chalk are often found in excellent preservation. There are specimens of fish, the bodies of which are rounded and entire, with their stomachs full and uncompressed, and delicate shells, with long spines, retain those fragile projections almost perfect. The accompanying wood-cut is a representation of one of these shells, (*plagiostoma spinosum*). In some instances, the sea-urchins and the sponges are filled with iron pyrites, instead of with flint; but in both cases, it is evident that the iron and the flint must have penetrated the interior of the shells in a liquid form, dissolved in some solvent. The fossilized plants found in chalk are confined to sea weeds, with the rare exception of an occasional piece of drift-wood; nor are there any land or river shells. All the records of the former condition of these parts of the world during the chalk formation serve to show that they were at the bottom of an open sea of considerable depth, the few terrestrial products being just sufficient to prove that the entire surface of the earth was not covered with water.

fig. 41.



It might have been inferred, from the soft structure of chalk, that if it were exposed to the same action of water which has worn down the harder rocks, it would exhibit still more strongly the effects of disintegration and denudation; and this is found to be the case. The thick beds of chalk have been deeply indented into valleys, and in some places have been completely swept away, as in Kent and Sussex, where the underlying Wealden strata are exposed on the surface. In the deep sea, where the chalk was deposited, there would be no disturbance of the water, and it is conjectured that the chalk beds were slowly upheaved, and, during the progress of elevation, were furrowed by the action of the waves.

CHAPTER VIII.

LOWER TERTIARY FORMATION.

Changes in the condition of the globe after the deposition of the chalk.—Altered character of organic remains.—Order of classification by species of fossil shells.—General character of tertiary strata.—Deposits of the London and Paris basins compared. — Differences in their structure and fossils. — Cuvier's discovery of extinct fossil quadrupeds.—The upper stratum of marine sand.—Strata of the Isle of Wight: their peculiar development in Alum Bay.—Character of the organic remains of this period.—Distinctions of the tertiary strata by their fossil shells.

After the extensive formation of the chalk, and its elevation above the surface of the sea, numerous successions of strata were deposited, consisting of marine, fresh-water and alluvial products, at different intervals, and during long periods, which abound in fossil remains of animals closely approximating to those of existing species. In the early stages of geological knowledge, these strata were supposed to be merely alluvial deposits of the same period, and to have been accumulated whilst the existing tribes of animals inhabited the earth. But a more careful examination of the strata and their fossil contents showed that their total thickness exceeded even that of the great chalk formation, and that most of the organic remains were those of animals which had long since been extinct. It further appeared that, as the strata were superposed on one another, and consequently approached nearer to the present period, the number of species similar to those now living increased; and among the fossil shells, numbers were found that were identical with those living either in neighbouring or in distant seas. The proportion of living to extinct species found in any rock thus became a guide to the arrangement of different strata in their geological positions, and the tertiary strata were consequently subdivided according to their supposed approach to the present order of creation. New terms have been introduced to designate the formations which are thus distinguished by their approximation to existing species. The first indication of approach to the present order of animated beings has been called the "eocene" period, from the Greek words *ήως* dawn, and *καινος* recent, "because the extremely small proportion of living species contained in these strata indicates the first commencement, or dawn, of the existing state of the animate creation."* The overlying strata are said to belong to the

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* Principles of Geology, by Sir C. Lyell.

"miocene period," because a minority only of fossil shells imbedded in the formations of this period are of recent species, the name being derived from μειων less, and καινος recent. The next group are called "pliocene," from πλειων major, and καινος recent, as the major part of the fossil shells of this epoch are referable to recent species. But the latter has been again subdivided into the newer pliocene, or "pleistocene," comprising the alluvial and diluvial depositions of still more recent times, immediately preceding the creation of man.

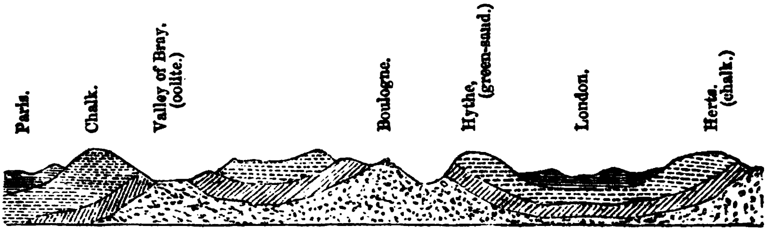
This system of arrangement and mode of classification have been strongly objected to on the ground that it is extremely difficult, if not impossible, to determine the numerical proportion of ancient and recent shells in each tertiary group and subdivision, because the limits of variation which may take place in shells by difference of age or of different circumstances in which the animals might be placed, are not ascertained. The difficulty of arriving at any certain conclusions from the examination of shells alone, has been proved by the different and even opposite opinions given by equally eminent conchologists as to the proportions of ancient and recent shells in the same strata. These opinions indeed are sometimes so contradictory, that whilst M. Deshayes, the original proposer of this system of arrangement, finds 50 per cent. of recent shells in the newer pliocene formation, other conchologists assert that it does not contain any.

We have thought it desirable to place before the geological student the new system of classifying the tertiary strata, because it has been adopted by most English geologists, and at the same time to present the objections against that system. It is our intention in this work to adhere to the previously established plan of classing the strata above the chalk generally as tertiary, subdividing them into groups of lower, middle, and upper tertiary formations. There is, indeed, no class of rocks the positions of which it is so difficult to determine as the strata above the chalk. They consist of clays, sands, limestones, and marls, most of them containing the organic remains of either marine, fresh-water, or terrestrial animals and plants, often succeeding each other within the space of a few feet; the strata being different in their mineral characters in different places, sometimes extending over a large tract of country, occasionally appearing only in small patches far removed from similar deposits, and bearing little or no analogy in the continuance or order of their succession.

From these various and opposite characters, it would seem that the aqueous tertiary deposits took place in shallow water near the coast, or in the estuaries of rivers; and that the nature of the depositions was changed, without any violent convulsion, by a slight elevation or depression of the land, or by the rising of the water; and that the character of the strata deposited depended much on the condition of the islands or continents that supplied the detritus carried down by the rivers into the sea.

Most of the beds resting upon the chalk, whatever be their mineral characters, may be considered as having been formed at the same geological period; and by noticing the varied nature of those depositions, we are enabled to perceive how great are the differences which different circumstances produce in the character of the strata belonging geologically to the same formations. The London and Paris tertiary deposits, technically called basins, serve as excellent illustrations of these structural differences, even when the circumstances were apparently alike. The accompanying section (fig. 42) shows the correspondence in main features of the strata surrounding London and Paris.

fig. 42.



The chalk of Hertfordshire, situated above the vale of Thames, dips under the London clay, rises again in the cliffs near Hythe, where the English channel intervenes, and it re-appears near Boulogne, resting upon the green-sand. It is cut through and separated in the valley of Bray, but again appears in hills on the north of Paris, and dips beneath the tertiary strata on which that city is situated. The circumstances of the two deposits are so nearly alike, that in those places at least it might be supposed the tertiary strata would correspond. It will be observed, however, that though the surrounding rocks are alike, the depositions from them, carried into the valleys, must have been independent of each other, as they took place in separated localities, one of which might have been covered with water when the other was dry land. So far as the first deposit on the chalk, they nearly agree. A soft, unctuous clay, called, from its capability of being moulded, "plastic clay," rests upon the chalk, interspersed with gravel and beds of various coloured sands, some containing shells and others without them. These beds of sands and clay are estimated to be 1000 feet thick in the Isle of Wight, where they have been extraordinarily distorted and lifted up vertically.

With the deposition of the plastic clay and its accompanying sands, the resemblance between the lower tertiary strata of London and Paris ceases. In the vale of Thames there is a thick bed of clay, called "London clay," varying from one hundred to five hundred feet in thickness. This clay is in some parts soft, in others hard; its colour varies from brown to blue; and it occasionally contains seams of gravel, but it may nevertheless be considered as one great and tolerably uniform argillaceous deposit. In the plastic clay under Paris and London, there are remains of marine animals intermixed with some freshwater shells, but the clay deposit of the Paris basin is very thin compared with that of London, and above it there occur beds of coarse limestone, called *calcaire grossier*, and *calcaire siliceux*, and beds of gypsum, the whole thickness of which deposits is about equal to that of the London clay. They may therefore be considered the "geological equivalents" of the London clay formation, because they were deposited in the same geological period; but if it were not for the direct evidence of superposition, confirmed by the unmistakeable boundary of the chalk, no one would suppose from their mineral structures that the two formations had any relation to each other. Neither the *calcaire grossier*, nor any mineral resembling it, is to be found among the tertiary strata in England.

The general character of the fossil remains in the London clay is marine, and some of the shells are similar to those found in the *calcaire grossier*, but they are few in number, and bear no proportion to the vast quantities that are embedded in the Paris formation. Some bones of turtles, and of crocodiles, branches and stems of trees, and lignite, or wood-coal, which sometimes occur in the London clay, indicate that the deposition took place not far from land; and from the occasional seams of gravel, it would appear that those portions formed parts of a sea-beach. Among these gravel beds are also found the remains of elephants and other terrestrial animals, but these are exceptional occurrences.

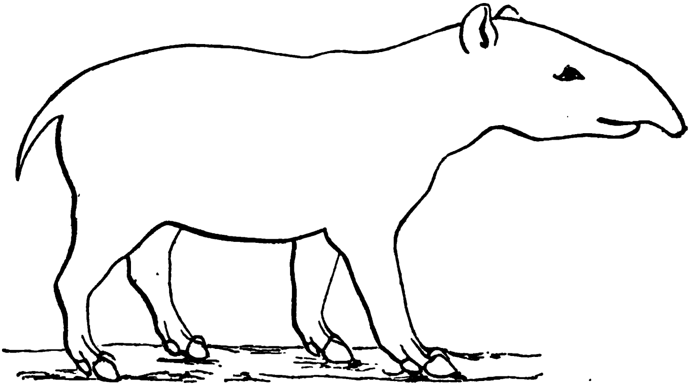
The fossil remains of the *calcaire grossier* also indicate that it was of marine formation, though probably deposited in deeper water than the London clay. But the most remarkable organic remains in connexion with the *calcaire grossier* are those in the gypsum and the gypsum marl that rest immediately upon it. This deposit is continuous and well defined, extending as a boundary line along the top of the *calcaire grossier* through a great part of the tertiary strata of France, though until lately supposed to be absent from those of England. It affords conclusive evidence that the deposition of the coarse limestone was followed by a long continuance of dry land, on which there lived tribes of animals, unlike in species, but resembling in general character, those that now inhabit tropical or much warmer climates.

The celebrated French naturalist, Baron Cuvier, was the first to discover that the bones found in the gypsum quarries near Paris were those of extinct animals. By applying his extensive knowledge of comparative anatomy to the development of the structure of the animals whose bones were embedded in the gypsum, he was enabled to determine not only the genera but the species, and to select from a mass of collected bones those that belonged to the same species of animal; and by this means to reconstruct the skeletons and exhibit the forms and sizes of those ancient inhabitants of the globe.

Among the bones found in the gypsum are those of turtles, birds, and of mammalian quadrupeds. The latter—with the exception of the remains of oppossums found in the Stonesfield slate, as before noticed—are the first fossil remains of mammalian quadrupeds that are met with in ascending from the lower formations to the upper. They were determined by Cuvier to be those of herbiverous animals belonging to the order which he named *pachydermata*, or thick skinned animals. One of these creatures, called palæotherium (ancient animal), seems to have combined the characters of the rhinoceros, the hippopotamus, the horse, the pig, and the camel, though its external appearance, as restored by Cuvier, approaches more nearly to that of the tapir, having a short trunk like that animal. It had three toes on each foot, and is supposed to have lived on marshy ground, and to have eaten the roots and stems of plants.

Figure 43 is an outline of this animal as it is supposed to have appeared when living.

fig. 43.



Another of the extinct animals developed by Cuvier was the anoplotherium, which was without defensive teeth, and about the height of a boar, though much longer. The bones of six species of birds, and of a few carniverous animals, allied to the wolf and the weasel, have been found in the bed of gypsum, so rich in the remains of fossil quadrupeds. It is a characteristic feature of the tertiary formations that this bed, filled with fossils of land animals, occurs between two strata that abound in marine deposits.

The *calcaire grossier* of the Paris tertiary beds is covered with marine sand. Though this bed of sand is scarcely recognised in England, there are scattered over some of the southern counties large blocks of sandstone, which are supposed to have belonged to corresponding beds that have been swept away by aqueous erosion. The immense blocks at Stonehenge consist of sandstone of this description.

The upper marine sand of Paris contains a thin stratum of compact silex, full of holes, which is well adapted for millstones, and under the name of Burrh stones are generally used in England for that purpose. The gypsum beds of Paris are also turned to good account in making the cement known as plaster of Paris; and some of the limestones found in the lower tertiary beds are extensively used in that city for building stone. The lower tertiary strata of the London clay have been principally useful in making bricks from the clays and sands; and balls of ironstone, called septaria, in the London clay, are employed in the manufacture of Roman cement.

The beds of marine sand which rest on the London clay at Hampstead and Bagshot terminate the series in the London basin; but in that of Paris there is a freshwater formation resting on the marine sands which is extensively spread over many parts of the continent, but has its representatives in this country only in the Isle of Wight. It consists of calcareous marls and hard sandstones, sometimes separated and sometimes intermixed, combined with a strata of pure limestone, and throughout the whole, there are embedded numbers of shells. The freshwater limestone in the neighbourhood of Paris varies in its structure, from being as soft as chalk, to constituting a stone almost as hard as flint. In places it resembles mountain limestone, and bears a high polish; but generally these limestones disintegrate on exposure to the air, and become converted into soft marl.

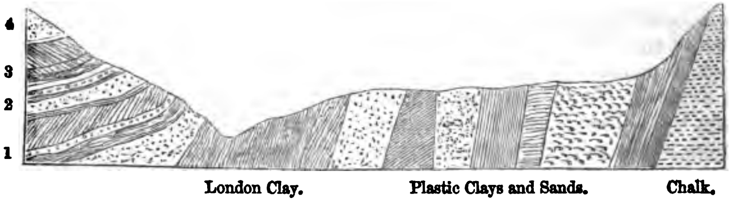
The Isle of Wight deposits differ from those of London and Paris in the greater development of the uppermost and lowest members of the group—the freshwater strata, and the plastic clays with the accompanying sands. Of these beds, a very remarkable section is fully exposed on the south of the island, at Alum Bay. Some violent convulsion, the source of which could not have been situated far below the chalk, has upheaved the beds in nearly vertical directions; and this displacement of the strata from their original horizontal positions, and the bright variegated colours of the sands, which always preserve a fresh surface, present one of the most beautiful and interesting geological sections that is anywhere to be seen. Mr. Webster, who has devoted much time to the examination and measurement of the strata in the Isle of Wight, states that the whole thickness of the beds at Alum Bay is not less than 3000 feet, of which the tertiary group above the chalk comprises 1400. Next to the chalk there occurs a thin marly bed, which is succeeded by a stratum of green, red, and yellow sand, sixty feet thick, a bed of dark blue clay with green sand containing septaria, 200 feet thick; then come beds of variously coloured sands, 320 feet in thickness; after which succeeds pipe-clay, with sands of different colours, occupying a space of 543 feet; in the middle of which deposits there occur beds of lignite, containing fossil fruits. The London clay, in a bed of 250 feet, interspersed with green sand, septaria, and shells, rests against the sands of the plastic clay. The freshwater formations occur immediately above the London clay, which towards the west inclines less vertically, and the strata gradually return to their horizontal positions in Headon Hill.

The strata of the lower freshwater formation consist of sandy, calcareous, and argillaceous marl. Some of them appear to be formed almost entirely of the fragments of freshwater shells, without any appearance of marine. From the quantity of these shells, and the regularity and extent of the strata, it seems evident that the spot where they now are was once occupied by a freshwater lake, in which the animals existed. Over this freshwater bed is a stratum containing a vast number of shells, considered by Mr. Webster to be marine, but numerous freshwater species have been found among them; therefore it is probable they were deposited in an estuary where marine and freshwater animals lived in common. Over that mixed formation, which is about thirty-six feet in thickness, there occurs a bed of fifty feet, consisting of limestone and marl, every part of which contains freshwater shells in great abundance, without any admixture of marine.

The tertiary depositions of the Isle of Wight have been recently carefully examined by Professor E. Forbes, who has discovered on the northern part of the island a succession of beds, corresponding with those of the upper deposits in the Paris basin, and of more recent formation than the strata at Alum Bay. Mr. Forbes estimates the thickness of these freshwater and marine beds at 600 feet; and he considers the development of the lower tertiary strata in the Isle of Wight to be more complete than in any other part of Europe.

The representation in fig. 44 of the cliffs at Alum Bay and Headon Hill, shows the regular succession of the lower tertiary strata in their most complete form, and the remarkable vertical positions into which they have been forced. The numbers 1, 2, 3, indicate the lower freshwater, the lower marine, and the upper freshwater deposits respectively.

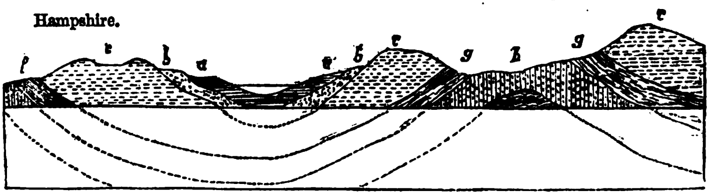
fig. 44.



We have taken the two principal deposits of London and Paris as types of this group of tertiary strata, which, from the similarity of the surrounding rocks, might have been assumed to be more closely analogous than most others of the same period, yet even here we see in how few particulars they are alike. In the Paris basin there is a much larger proportion of calcareous matter and less of argillaceous than in that of London, whilst the occurrence of beds of gypsum in the former shows that there was an abundant chemical deposit of sulphate of lime, of which mineral there are only feeble traces in the London clay. The presence of sulphuric acid in the London clay is, however, manifested by the impregnation of the water that percolates through it with sulphate of magnesia and sulphate of lime. Those salts frequently impart a disagreeable taste to the water that is obtained from wells sunk in the London clay, and the springs that issue from it occasionally hold so much sulphate of magnesia in solution as to possess medicinal properties. The springs at Epsom, for instance, are celebrated on this account; the water, when evaporated, affording a considerable portion of the salts named from that place.

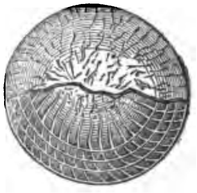
The succession of the strata in the Isle of Wight in relation to those in the south of England will be best understood by the accompanying section, from which it will be seen that some elevating force, operating under the centre of the island, has upheaved the chalk and the underlying beds. The masses of green-sand and other rocks thus brought to the surface have been carried away from the axis of elevation, and the chalk cliffs on the north-east and south-west have been thus separated.

fig. 45.



The fossils of the lower tertiary beds, in addition to those of the land animals found in the gypsum, comprise a great range of animals and vegetables, most of which were adapted to live in warmer climates. In the London clay of the Isle of Sheppey, there occur great abundance of the fruits of trees and shrubs of the kind now only to be met with in the tropics; and near Harwich have been found the trunks of palms. The species of fossil shells in these strata are almost innumerable. They are remarkable for approaching in general character, and in some instances exactly resembling, those of existing species found in distant seas possessing a warm temperature. The zoophytes, which in earlier depositions are abundant, become more rare, but the remains of foraminifera, which approach to corals in the nature of their formation, are so numerous as to constitute the mass of some of the beds in the Paris basin. The shells called nummulites, from their fancied resemblance to a small Roman coin (fig. 46), are most remarkable for their abundance. The whole family of cephalopoda, so called by Cuvier because the organs of motion are placed round the head, seem to have become nearly extinct in the tertiary period, whilst that of the gasteropodes, which inhabited univalve shells and moved on their stomachs, like snails, was greatly increased; and many new species, before unknown, were introduced. Of fishes, there are found the remains of sharks, a saw fish, some gigantic rays, and some relics, before final extinction, of the ganoid order of fishes.

fig. 46.



In the mode of classification introduced by M. Deshayes, to which we have alluded, he makes two grand divisions of stratified formations; first, those which contain no shells analogous to existing species, and secondly, the strata which contain a greater or lesser number of species analogous to those now living. The first class comprises the secondary rocks and all those beneath them; in the other are comprised the tertiary formations. The latter are sub-divided into three groups, according to the proportions of shells they contain of recent species, and to which the names of eocene, miocene, and pliocene have been applied, as before explained. In the older or lower group, which have been described in this chapter, M. Deshayes places the tertiary formations of Paris and London, the Isle of Wight, and of a part of Belgium, a small part of the Gironde, and the tertiary strata of the Vicentin. In this group he found fifteen hundred species of shells, of which only thirty-eight are analogous to existing species. Of this vast number none are said to have any analogy with those in the chalk or the strata below it, and only forty-two species are found in the tertiary series above; a great change having, it is supposed, been effected in the character of the tribes of shell-fish between the lower and middle tertiary periods.

The middle group, to be described in the next chapter, comprises the marls of Touraine and other parts of the Loire, a great part of the Gironde, of Dax, Austria, Hungary, and Poland, and a small portion of the sub-Apennine Hills, near Turin. The shells in this group consist of nine hundred species, of which eighteen per cent. are analogous to those existing, and seven hundred and seventy of the species are extinct.

The upper group, in the classification of M. Deshayes, comprises the sub-Apennine Hills, the whole tertiary strata of Sicily, the Morea, Perpignan, some small districts bordering the Mediterranean, and the tertiary deposits in Norfolk, called the Norwich crag. Seven hundred species of shells have been distinguished in this upper group, of which more than half are analogous to living species. Of all the shells in the tertiary strata only thirteen species have been found common to all. It is a remarkable fact also that the living species which are analogous to those in the lower tertiary groups are the inhabitants of tropical seas far distant from the places where their fossil types are deposited, whilst in the most recent group the living species to which the fossils are analogous inhabit the neighbouring seas.

CHAPTER IX.

MIDDLE TERTIARY FORMATION.

The difficulty of distinguishing tertiary strata.—Suffolk crag.—Corresponding strata extensively distributed on the Continent.—Mineral characters of the formation.—Proportions of recent to extinct fossil shells.—Geological period of the Suffolk crag determined by position as well as by fossils.—The red crag.—Fossil remains of large quadrupeds.—Formation of the middle tertiary strata.—Deposition in the Valley of the Danube.—The ages of volcanic lavas determined by enclosed fossil shells.

It is extremely difficult to draw a distinctive line between the groups of tertiary strata; for the land, freshwater, and marine formations are interpolated closely together and without dependence on similar deposits at the same periods, even in localities not far distant; nor is it by any means easy to determine to which group any specimen may belong, especially as it often happens that the upper tertiary beds occur resting immediately on the chalk or other secondary rocks, without any accompanying lower beds of the series. When the only sure test of superposition is absent, the best means that remain are the examination of the organic remains; and if the fossils in one isolated bed correspond with those of another, the relative position of which is known by the associated strata, the comparative age may be inferred with great probability of correctness.

In the arrangement which we have adopted, the lower group comprises the succession of marine beds in the London and Paris basins, from the plastic clay to the upper marine sands, and includes also the beds of freshwater deposits which rest upon the sand in the Paris and Isle of Wight series. Those freshwater beds complete the tertiary formations near Paris, and seem to constitute a boundary line between two periods sufficient to justify the consideration of the more recent depositions in a separate chapter. It must be borne in mind, however, that the tertiary strata in different localities are so various, even when known to have been deposited at the same periods, that the periodical equivalent of a freshwater stratum in one part of a country may be a marine deposition in another. In such cases it is vain to look for similarity in organic remains, and the nearest approach to resemblance must be traced in the next occurring beds of the same kind of deposition.

The middle tertiary (miocene) formation occurs in England almost exclusively on the coast of Suffolk, extending along the shore for forty miles, and it nowhere attains a greater thickness than forty feet. It is associated with the upper tertiary in Norfolk; and the deposits of shelly sands, pebbles, and marl, of which both are composed, have retained the name of crag, a provincial term signifying gravel. On the Continent the middle tertiary beds cover extensive tracts both of low land and of lofty hills, and constitute important geological features. They occupy a considerable portion of the west of France, filling up the basins of the Loire and the Garonne, they cover a great part of the valley of the middle Rhine, the whole of the valley of Switzerland between the Alps and the Jura, and they proceed towards the north-east from Switzerland, following the course and partly occupying the valley of the Danube. They may be traced spreading into extensive series near Vienna and in Styria; they occur again in the plains of Hungary, and in Poland and Russia; they are met with in North and South Italy, and on the shores of the Mediterranean and in the South of Spain. As the successive beds of this formation are exclusively marine, they point out extensive districts in Europe which were covered by the sea at a period more recent than the chalk.

The middle tertiary beds consist chiefly of a series of conglomerate sandstones and marls associated with lignite, and are often overlaid by coralline limestones. They are abundantly fossiliferous, and occasionally contain the remains of mammaliferous land animals. These general characteristics are, however, so frequently varied in different situations, and the rocks on which the tertiary beds rest are so different, that it would often be impossible to determine to what class of rocks they should be referred without a comparison of their fossil contents with those of living species. It is under such circumstances that the test of per-centage of recent shells, introduced by M. Deshayes and Sir Charles Lyell, to determine the comparative ages of the tertiary strata, proves of great service; and if not applied too rigorously and exclusive of other evidence, it may be relied on with considerable confidence.

The per-centage of recent to extinct animals in the fossil shells of the lower tertiaries is estimated to be only 3½; those of the middle tertiary beds at 17 per cent., and those in the upper formation at 45. Above these there occurs a still more recent deposit (newer pliocene), which some geologists have termed the quaternary formation, that contains about 95 per cent. of living species. Resting upon all are diluvial and alluvial deposits, in which the fossil shells are almost entirely those of animals of species now living. These proportions are so widely different, that when the characters of the fossil shells are correctly ascertained there can be little hesitation in deciding to which of the tertiary formations the specimen containing them belongs. It cannot, indeed, be expected, in such extremely various deposits, that a close correspondence can be observed in the relative numbers of the recent and extinct species; yet the far greater prevalence of recent shells over those that are extinct will in nearly all cases serve to determine with which formation any stratum is to be classed, especially if such test can be confirmed by corresponding peculiarities, in mineral structure and in the species of fossils, with other rocks that have their assigned positions. Let us take, for example, the Norwich and Suffolk crags, on which English geologists have bestowed great attention, as they are almost the sole relics of the upper tertiary formations in England. The proportion of recent to extinct fossils in the Suffolk crag is estimated at about 17 per cent., those in the Norwich crag at 45. As both these rocks rest on the chalk, they might, but for this disproportion in the number of recent and extinct species, have been considered as belonging to the same formation, and both have been classed with the lower tertiaries of the London basin. That difference in their fossiliferous characters, however, points out their distinction from the lower formation and from each other, and the evidence of superposition comes to confirm the inference of the relative ages of the rocks founded on the disproportionate numbers of recent shells. The Norwich and Suffolk crags are quite separate depositions, and occur together only for a short space near Ramsholt. That point of junction shows the Norwich crag resting upon the crag of Suffolk, which is ample confirmation of the per-centage test of their respective ages. In some places the Suffolk crag rests directly on the London clay, and from the nodules of iron, and from some characteristic fossils found in the red crag, it is conjectured to have been formed in a great measure from the washing away of that bed on the sea shore.

The Suffolk crag is divided into two formations, called the red and the coralline crag. The latter, which is the lowermost bed of the two, is composed of calcareous sand, containing shells, corals, and sponges, well preserved; the sand itself being chiefly derived from decomposed corals. The coralline crag extends for a length of twenty miles, and is about three or four miles in breadth, occupying the space between the rivers Alde and Stour. The red crag is a rich shelly bed about forty feet thick, strongly coloured by iron. Along the line of coast where the crags are exposed they are generally covered with superficial deposits of clay, sand, and gravel, which sometimes form cliffs three hundred feet high, at the base of which the beds of crag may be seen: in other parts the crag is elevated on the shore, and may be examined through its whole thickness.

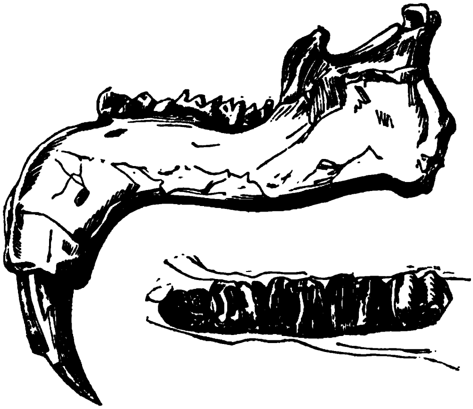
The proportion of recent to extinct fossils corresponds with the percentage assigned to the middle tertiary formations, and as the comparative age of the crag formation can be distinctly traced by superposition, it serves, insignificant though it be in extent and depth, as a landmark to point out the positions of distant beds of greater territorial importance; and it becomes a standard of comparison to which the test of percentage may be applied.

The middle tertiary group is well represented in the valley of the Loire by extensive beds of shelly marl called "faluns." Between Sologne and the sea they rest upon a regular succession of the older rocks; from gneiss, clay-slate, coal measures, and chalk, to strata corresponding with the upper freshwater beds of Paris.

The faluns of Touraine agree with the shelly portion of the crag of Norfolk and Suffolk and their associated strata, in being deposited in thin layers. They often bear a strong resemblance to the red crag of Suffolk in colour, and in their decomposing state; and the shelly marl is employed in the Touraine, as the crag is in Norfolk and Suffolk, for manure. Fossil remains of the mastodon are very abundant, and associated with them are the bones of the palæotherium, the hippopotamus, the rhinoceros, the boar, the horse, and the stag, mingled together with those of the whale, the dolphin, the morse, and numerous species of fishes. Some of the animated creatures of this, as of preceding periods, were of gigantic size. Among the remains of fishes found in the Suffolk crag are the fossil bones of a shark, from which it is inferred that the living animal must have had a vertical gape of at least three feet, and four feet broad, and an entire length of not less than sixty-five feet.

The most remarkable of all the fossils of mammaliferous quadrupeds found in the middle tertiary formation are a few bones of an enormous creature called the dinotherium, which is supposed to have been the largest of terrestrial animals. The most perfect remains of this species that have yet been found were dug out of the middle tertiary beds on the banks of the Rhine, at Epplesheim; but as they consist only of some bones of the head, a few teeth, and tusks, the exact form of the animal has not been determined. From an examination of these few bones it has, however, been ascertained that the dinotherium was an aquatic herbivorous animal, adapted to inhabit the banks of lakes, and that the body, of which the bones formed a part, must have been eighteen feet long. It had a short proboscis, and large curved tusks, fixed into the lower jaw, grew downwards like those of a walrus. Some of the few bones that have been discovered are represented in the accompanying woodcut. A crown tooth of the dinotherium, found near Grenoble, was in as perfect a state of preservation as if it had been quite recent, the enamel being very hard and brilliant.

fig. 47.



In the valley of Switzerland, from the northern base of the great mountain chain throughout the lower country, there occurs a soft green sandstone, called *molasse*, which has been considered to belong to the middle tertiary period, but on this point geologists are not agreed. The sandstone contains few fossils by which its relative age can be determined, and in some places the *molasse* is covered by Jura limestone and oolite, so that, if the whole of the green sandstone be the same continuous formation, the *molasse* must be removed from the class of tertiary strata and be placed among the secondary rocks.

All the middle tertiary beds hitherto noticed are considered to be marine formations; the occasional remains of land animals they contain being regarded as accidental deposits brought down by flooded rivers that emptied themselves into the bays and estuaries wherein the beds accumulated. But independently of those partial indications of elevated land there are formations containing exclusively freshwater shells and remains of land animals, which have evidently been deposited above the level of the sea in detached lakes. The test of per-centage is not readily applicable to freshwater shells, as it requires local knowledge of the species of mollusca existing in the neighbouring lakes to determine the proportions of recent and extinct species, but in many parts of France they have been sufficiently examined to associate several of the local freshwater formations with the middle tertiary strata.

There is a class of rocks to which it might be presumed it would be perfectly useless and absurd to apply the test of conchology for ascertaining the geological period of their formation; nevertheless, the same test by which the relative ages of marine formations are determined, has been successfully applied to discover the periods of volcanic eruptions. The lava and ashes of a volcano bursting out under the sea or on an island would cover and entrap the animals living in the surrounding water or on the shore, and in like manner the lava and scoriæ of an inland volcano would cover and enclose terrestrial products. These are frequently met with in volcanic countries, and shells have been collected in sufficient quantities to estimate the proportions of recent or extinct animals that existed at the time of the respective eruptions. Investigations of this kind must necessarily be imperfect, and from the smaller number of specimens collected and the injury sustained by sudden heat, any evidence deduced from them must be liable to error; but it would appear from the shells examined that they are mostly referable to the middle tertiary period.

We have deferred noticing the action of volcanoes until after the description of the regular succession of stratified rocks; nor shall we be induced even by this ingenious classification of lavas with tertiary formations to enter now into that interesting branch of our subject, further than to draw attention to the fact, that the history of former worlds has at successive periods been thus cast by molten rocks on everlasting tablets; and that as the works of man in ancient times have been brought to light at Pompeii and Herculaneum from their tombs of volcanic ashes, and at Nineveh from tumuli of drifted sands, in like manner there may be excavated from under the lavas of extinct volcanoes records of the condition of the globe and its inhabitants thousands of ages before man was created.

CHAPTER X.

UPPER TERTIARY FORMATION.

Complication of strata in recent geological periods.—The sub-Apennine hills.—Circumstances of their deposition under the sea.—Subsequent elevation.—Depositions of marine shells on the summits of the hills of Rome.—Recent character of the strata of Sicily.—Norwich crag.—Freshwater formation at Œningen.

As we approach nearer to that condition of the globe which immediately preceded the creation of living animals, we not only perceive in the fossil remains of the former inhabitants of the earth a closer approximation to those now existing, but also a nearer distribution of them into those parts of the world where they now dwell.

There are numerous indications of important changes having taken place after the deposition of the extended group of strata comprised in the middle tertiary formation. Those changes were not effected by sudden convulsions; but they appear to have progressed gradually, by the action of external and internal agencies in different parts of the world at the same periods, so as to present no distinctive marks by which they can be divided into separate epochs. The comparison of extinct with recent species in the fossils of various strata—even admitting to the fullest extent the correctness of the principle and accuracy in the results of examination—can only be applied to test the relative ages of detached strata, and presents rather a gradual approximation to the present state than any breach of continuity that may serve as a distinguishing boundary.

When the character of the strata depended entirely on local peculiarities, as those deposited after the chalk appear to have done, attempts to distinguish one formation from another by distinctive marks must in a great measure prove abortive, and the difficulty increases as we draw nearer to recent deposits. It has been already seen, that even the depositions resting immediately on the chalk are extremely various in their mineral structures and in their fossil contents, and that they differ greatly in the periods of their formation. When the land was raised from the bed of the ocean and the disintegration of the rocks which formed the subsequent depositions occurred—in some places in valleys, in others in freshwater lakes, or in the estuaries of great rivers, and at the same time under the sea—those contemporaneous formations must necessarily have varied with the circumstances under which they took place. When it is considered that the *débris* of the rocks from which the tertiary strata are composed would be different according to the exposure on the surface of the different underlying beds, from the chalk to the granite, we shall see at once that it would be impossible there should be uniformity in the composition of tertiary strata, even at the same periods, in different localities. If to these causes of difference, which must obviously have existed, there be added the gradual or sudden elevations of the land in different parts of the world—which geological investigations place almost beyond a doubt—we see reason not only why the mineral characters of rocks belonging to the same period should vary, but also why variations could have occurred in the conditions suited to animal life, by which the inhabitants of the same district and the proportions of species might be changed. It seems impossible, therefore, to establish any satisfactory division between the groups of strata deposited under such constantly varying circumstances; and though many geologists have made distinctions between the upper tertiary formations and those which approach still nearer to recent pereods, we shall adhere in this respect to the system of M. Deshayes, and class all those regular fossiliferous strata that contain more than one half of recent shells with the upper tertiary formation.

The most extensive deposit of upper tertiary beds of which there is any authentic account occurs in Italy. The Apennine mountains, which branch from the Ligurian Alps and extend down the centre of that peninsula, have on the west and east accompanying ranges of lower hills called sub-Apennines. They have evidently been formed from the washing down of the mountains; which are composed of secondary rocks, and rise to a height of 8000 feet. The entire mass of the sub-Apennine hills, which in no place attain a greater height than two thousand feet, is of tertiary formation, with strata laid conformably on the sloping sides of the parent mountains. The general mineral structure of the beds consists of a brown and blue marl, sand, clay, and calcareous tuff, and they abound in marine shells; from which it appears that though they now occupy a very elevated position, they must at one time have formed the bed of the sea. Such an immense mass of matter would have required ages for its deposition; and from the differing character of the fossil shells in the northern part of the sub-Apennine range, nearer the Alps, from those in the southern elevations, it is supposed that they were raised gradually during a period sufficiently long for a marked change to have taken place in the condition of animal life in the sea.

Four separate periods of formation are said to be indicated by the fossils in the sub-Apennine range. Commencing with Piedmont, some middle tertiary beds occur; and proceeding southward, the upper tertiary formation presents itself in full force; and, as the neighbourhood of Vesuvius is approached, the proportion of extinct shells diminishes till the proportion of recent fossils is upwards of ninety per cent., and the strata are classed by Sir Charles Lyell with the tertiaries of Sicily, and called newer pliocene.

As the range of the sub-Apennine hills may be considered the type of the upper tertiary formation, we subjoin an abbreviated description of their geological characters from Sir Charles Lyell's "Principles of Geology":—

"The most important member of the sub-Apennine formation is a marl which varies in colour from greyish-brown to blue. It is very aluminous, and usually contains much calcareous matter and scales of mica. It often exhibits no lines of division throughout a considerable thickness; but in other places it is thinly laminated. In some of the hills near Parma, the marl attains a thickness of 2000 feet, and is charged throughout with shells, many of which are such as inhabit a deep sea. They often occur in layers, so as to indicate their slow and gradual accumulation. They are not flattened, but are filled with marl. Beds of lignite are sometimes interstratified; subordinate beds of gypsum also occur in many places. The marl constitutes very frequently the surface of the country, having no covering of sand.

It is sometimes seen reposing immediately on the Apennine limestone; more rarely gravel intervenes. Volcanic rocks are here and there superimposed, as at Radicofani in Tuscany. Several of the volcanic tuffs in the same place are so interstratified with the marls as to show that the eruptions took place in the sea during the older pliocene period. The other member of the sub-Apennine group, the yellow sand and conglomerate, constitutes in most places a border formation near the junction of the tertiary and secondary rocks. In some cases we see sand and calcareous gravel resting immediately on the Apennine limestone, without the intervention of any blue marl. Between Florence and Poggibonsi in Tuscany there is a great range of conglomerate of the sub-Apennine beds, which is seen for eleven miles continuously. The pebbles are chiefly of whitish limestone with some sandstone. On receding from the older Apennine rocks the conglomerate passes into yellow sand and sandstone, with shells, the whole overlying the blue marl."

The preceding description of these extensive upper tertiary beds will apply in a great measure to all similar deposits. After the sub-Apennine hills were formed and raised from the sea, they must have been wasted by the disintegrating action of rivers and torrents even more extensively than the harder rocks of the Apennines. Of this there are numerous proofs in the deep excavated valleys, surrounded by hills, on the tops of which there are deposits of fresh water shells and volcanic tuff. It must, therefore, be inferred that subsequent to the elevation of the sub-Apennines, lakes of freshwater collected in the hollows, wherein shells were deposited until the pent-up water burst its barriers and forced a course to the sea; and after a long succession of ages the beds of former lakes became, by the excavating action of water, the tops of hills. It was in this manner that the seven hills of Rome were formed, for they are capped with volcanic tuff and freshwater remains. It is from facts such as these that we acquire some notion of the immensity of time that has been occupied in effecting changes on the surface of the earth. Since the earliest historical records the river Tiber has flowed in its present bed, nor has the face of the country round Rome been notably altered; if, therefore, these enormous excavations were produced only by the continued action of the causes that have been in operation for the last 2000 years, it must have required countless ages to have worn away the mountains that once made valleys of the hills of Rome.

In Sicily, the upper tertiary strata of the most recent formation are exhibited in a striking manner in connexion with volcanic products, being deposited in beds of great thickness, and elevated upwards of 3000 feet above the level of the sea. About one-third of the island, in the northern and central parts, is occupied by these beds.

The Norwich crag is of more recent origin than that of Suffolk, which fact is determinable not only by its superposition in a few points where they appear together, but by the greater proportion of fossils identical with existing species, the recent fossils in the Norwich crag amounting to upwards of forty per cent. The remains of mammalian quadrupeds in that portion of the crag formation are very abundant, those of elephants especially being remarkably numerous.

Near the coast, at Cromer, there is a submarine forest, which extends some distance into the sea, the trees standing upright as they grew.

Branches of these trees, and elephants' teeth, are often brought to the surface by the fishermen, when dredging for the oysters that now live on the alluvial deposit which rests upon and imbeds that ancient forest. It is stated by Mr. J. Woodward, in his "Geology of Norfolk," that upwards of 2000 teeth of mammoths have been dredged up off the Norfolk coast from the bed of lignite and lime underlying the drift.

The upper tertiary formation, corresponding with the sub-Apennine beds, is extensively distributed in the Morea, in the islands of the Eastern Archipelago, in the south of Russia, and in the Valley of the lower Rhine. These tertiary beds do not, however, contain similar proportions of recent and extinct species of fossils. Those of Sicily, and other volcanic regions, are more recent than any other marine formations; it being generally found that where the land has been frequently agitated and upheaved by volcanic agency, the proportions of recent to extinct species of shells are the greatest.

The following table exhibits the per-centage of fossil shells corresponding with those of living species in the principal deposits of the tertiary formation.

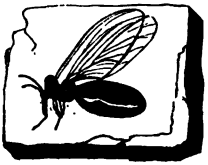
Sicily	95·0	Touraine	22·7
Italy	41·8	India	17·5
Norfolk Crag	40·1	Angus	15·0
Suffolk Crag	00·0	Rome	7·5
Vienna	28·2	London	5·0
Baden	26·2	Paris	3·4
Bordeaux	22·9		

There is an extensive freshwater formation at Œningen, near Constance, which appears to belong to a more recent period than any of the marine tertiary deposits. The quarries worked in these strata have long been celebrated for the great number and variety of organic remains extracted from the rock, consisting of the fossilized bones of quadrupeds, birds, fishes, reptiles, and plants. It was formerly supposed that fossilized human bones were imbedded, but they have been ascertained to be those of an aquatic salamander. The strata are chiefly indurated calcareous marl and freshwater limestone.

No bones of elephants, or of other animals of tropical climates, have been found in the Œningen beds; from which circumstance it has been inferred that the temperature of that part of the earth had become much cooler before their deposition, and had approximated to its present state.

In several other parts of Europe there are patches of gravel and freshwater depositions found resting upon the upper marine tertiary formation. At Aix, in Provence, there is a group of tertiary strata remarkable for the high state of preservation of the organic remains of fishes and insects. The latter have their wings extended, and all the other delicate parts of their organization quite perfect. The accompanying representation of one of these insects, apparently arrested in the act of walking, is copied from Dr. Mantell's "Wonders of Geology." At Brentford, there is a bed of gravel in which numerous remains of mammoths have been found; and at Greys Thurrock, in Essex, there is a freshwater bed more recent than the one at Brentford.

fig. 48.



CHAPTER XI.

DILUVIAL AND ALLUVIAL DEPOSITS.

Present division of the earth into land and sea.—Change of climate.—Erratic blocks from distant mountains: their supposed transportation by glaciers.—Present physical features of England then determined.—Raised sea beaches.—The works of man imbedded in alluvial deposits.—Gradual elevation of the land.—Influence of alluvial depositions on the fertility of soils.

PREVIOUS to the tertiary periods there are no indications that the surface of the earth was divided into the continents, seas, and islands, with boundaries as they are now distributed. The greater part of Europe was covered with water long after the chalk was elevated. Tertiary strata, abounding in marine fossils, resting on elevated parts of the Alps and Apennines, show that those now lofty mountain ranges were then but partially if at all raised above the level of the sea. These marine depositions serve clearly enough to indicate the tract of country covered by the sea at the commencement of the tertiary era, by which means it has been ascertained that all the eastern part of England, extensive tracts in the centre and in the south-west of France, the Auvergne, the northern part of Italy, nearly the whole of Belgium, and Denmark, and Hungary, with the principalities of Wallachia and Moldavia, the north of Germany, and by far the greatest portion of Russia, were covered by water since the commencement of the deposition of the older tertiary strata. The elevation of the land after that period seems to have been generally conformable to the present geographical divisions of the globe; though hills and valleys and islands have been formed by the subsequent alluvial or volcanic depositions and by the erosive action and transporting power of water and ice. There is evidence, in the numerous and large accumulations of alluvial matter, that after the deposition of the tertiary strata great changes took place on the surface of the earth, and that a long period elapsed before the creation of man. The climate of the northern part of the globe, which had been sufficiently hot for the growth of tropical plants and for the existence of tropical quadrupeds, became, there is reason to believe, as cold as the arctic regions; and during that frigid time, which has been called by some geologists "the glacial period," floating icebergs and shifting glaciers brought down from the mountains masses of stone, severed from the rocks by the expansive action of frost, and spread them in the forms of immense blocks, boulders, gravel, sand, and loam, over the lower hills and plains to a distance of a thousand miles. Immense blocks of granite scattered over the plains of Russia and Poland correspond exactly with the granite of Lapland; and masses of gneiss, sienite, trap, and porphyry that are found in Pomerania, Holstein, and Denmark, correspond with rocks of the same character in Sweden and Norway; and at no nearer point than in the mountains of those countries do any rocks like them occur. In the country near the Alps blocks of enormous magnitude that have been detached from the higher mountain peaks are deposited on the tops of other mountains of less elevation, at distances many miles apart. Round the Lake of Geneva, at heights of two thousand and three thousand feet, masses of rock have been deposited from the higher Alps, which are altogether distinct in mineral character from the mountains on which they rest. Nor are similar instances of "erratic blocks," as they have been termed, of rare occurrence in this country. A most remarkable block of this kind, weighing ten tons, has been deposited on the top of the Pentland Hills, at a height of eleven hundred feet above the level of the sea; the nearest rock of a similar kind from which it could have been detached being at a distance of fifty miles.

It may appear incredible that such masses of stone should have been transported to the places in which they are found from far distant mountains; but if we admit the agency of ice it may readily be accounted for by what is seen going on at the present day. Icebergs have been observed in the Antarctic regions loaded with masses of rock and earth estimated at not less than fifty thousand tons weight. These icebergs were floating northwards and melting as they approached the equator, and they would ultimately deposit their loads of rock and earth on the bed of the sea. Evidence of the transporting power of glaciers is to be distinctly seen in the valleys at the foot of the Alps. Masses of rock detached by the frost from the exposed precipices fall upon the glaciers, where they are collected in great masses. By the gradual descent of the glaciers the ice is brought within the melting temperature, and the loads of rock are deposited in the valleys, where they form masses called *moraines;* and these are being continually worn down and carried away into the lower valleys by mountain torrents. The masses of ice descending with their loads of sharp-pointed rocks cut lines on the sides of the ravines against which they rub in their descent, and this action, continually progressing at different levels, in the course of time carves out series of parallel furrows which produce a striated appearance. Similar marks are observed to be impressed on the surfaces of the erratic blocks, and are attributed to this grinding action during their passage down the mountain ravines, till they were launched on their glacier ships into the sea, and borne to the spots where they are deposited.

There can be no doubt that these erratic blocks were generally detached from far distant mountains, for they are not only altogether different from the rocks whereon they rest, but none like them are to be found for hundreds of miles, whilst they exactly agree in mineral structure and fossil contents with the distant rocks to which they are attributed.

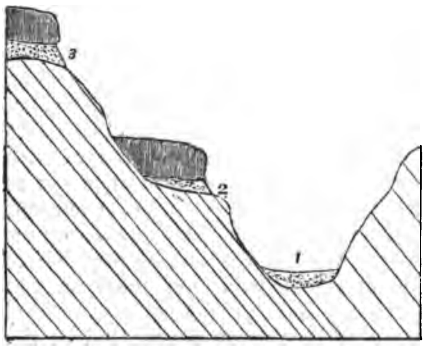
The geological period at which these extraordinary depositions took place may be also indicated. The blocks are not imbedded under any of the regular marine formations, but are found lying on the surface, most frequently resting on tertiary beds; from which fact we are enabled to determine that the agencies, of whatever kind, that effected these mighty movements of rocks, were exerted at a comparatively recent geological period. There is evidence, also, in the limitation of the "drift" to certain districts, that the main features of the country, its mountain ranges and its valleys, were at that time nearly the same as at present. For instance, the *débris* from the Cumberland mountains of Ravenglass and Muncaster have been clearly traced along the west of the chain of hills that extends along the centre of England from Yorkshire into Somersetshire, but they are not perceptible on the eastern side; from which it appears that the water or ice that bore along that quantity of matter was confined to the west by those lofty hills. A similar limitation of the drift, though probably occurring at a later period, is witnessed in Warwickshire and Gloucestershire, where the quartzose pebbles that have been detached from the Bromsgrove Lickey are spread over the surface of the country to the Cotswold hills, where their course has been stopped, excepting at two points, which, being lower than the rest, permitted the drift to pass through, and to be scattered on the other side. The cliffs on the coast of Norfolk and Suffolk consist for the most part of clay, loam, and sand, partly stratified and partly not, among which occur pebbles of granite, porphyry, lias, and chalk interspersed. The granite and porphyry must have been transported there from Scandinavia, at the same time that the blocks of gneiss and porphyry were spread over the plains of Pomerania and Denmark, whilst the lias and chalk were derived from hills not far distant.

Geologists are not agreed as to the nature of the agency by which the blocks and "drift" that cover the surface of almost every country in the north and south were deposited in their present positions, but all concur in opinion that the matter was derived from the *débris* of hills and mountains more or less distant. Those who suppose that the materials were transported by ice, which would best account for the phenomena, are met with the difficulty of accounting for the change of climate, from one suited to the existence of numerous elephants and tigers, and other quadrupeds that now inhabit hot countries, to a climate as rigorous as that of Iceland. It is conjectured, as a means of overcoming this difficulty, that after the tertiary formations, the mountains were much higher than they now are, and that there was high land in the Arctic regions, the elevation of which would cause a great diminution of the temperature. The subsequent lowering of the mountains by disintegration or general depression, and the depression of the land in the Arctic sea, have, it is supposed, moderated the climate to its present state. On the other hand, the geologists who imagine that the blocks of stone were removed by violent agitations of water, and thus carried to distant lands, have no less difficulty in explaining the cause of such convulsive disturbances; and they have the still greater difficulty to surmount, of accounting satisfactorily for the deposition of enormous blocks of rock on the summits of high mountains. The glacial, or ice theory, seems the more probable of the two; and if a long succession of ages be granted for the deportation of the drift, before the land was raised to its present elevation, the floating icebergs might have carried their freights of rocks, without supposing any great diminution of the temperature of this part of the globe.

The accumulation of gravel and sand on the sea-shore, which has been subsequently raised by the gradual elevation of the land, is another means by which superficial deposits have been formed. There are numerous instances of this kind in which the raising of the beach is clearly indicated to have taken place within recent times by the discovery, among the gravel and sand, of specimens of man's handiwork. In Norway and Sweden there is evidence that the land has for many years undergone a gradual upheaving, at the rate of about five feet a century; the elevation being greater towards the north than in the southern parts. On the coast near Stockholm there are horizontal beds of sand, loam, and marl, containing shells of species identical with those of animals now living in the Baltic, and imbedded among them have been found parts of a ship that was built before the use of iron was known. The upper layers of these diluvial beds, which have been once a portion of the shore, are now raised sixty feet above the sea level. There is a peculiarity in these beds of shells which gives them additional interest, as they serve to prove that at the time they were lying on the beach the Baltic was then, as it is now, a land-locked sea. In consequence of its narrow outlet of communication with the German Ocean the water of the Baltic is not so salt as the sea, but only brackish, and contains only one-fourth the proportion of salt that is held in solution by the water of the ocean, and the shell-fish that inhabit it are of the species peculiar to brackish water. These distinguishing characters are observed in the fossils contained in the raised beaches, and by the conformation of those fossil shells geologists are thus enabled to throw light upon the physical geography of the globe at the earliest periods that it was inhabited by man.

It is in volcanic countries, however, that the most remarkable elevations of the sea beach and beds of rivers are observed. In the bay of Puzzioli, not far from Naples, there are strata of marine formation, raised to a height of twenty feet above the level of the water, which contain fragments of pottery mingled with shells. The latter retain their colour, and are all of them of the same species that are now living in the neighbouring seas. In the more immediate neighbourhood of Naples there are beds of the most recent marine formations raised to a height of fifteen hundred feet. In the Auvergne, a district of extinct volcanoes, there occur interesting vestiges of beds of gravel, covered with lava, lying one above the other to a considerable height. The section, fig. 49, represents the positions of these alternate beds of lava and gravel. There are three alluvial formations represented, at different heights; one on a level with the bed of the river, the second elevated above it, and the third raised to a height of 700 feet. The uppermost bed of gravel consists of pebbles of granite brought down from the surrounding mountains without any admixture of lava; in the second and third gravel beds pebbles of lava are mingled with the primary rocks; from which it may be inferred that the deposition of the uppermost gravel, which once formed the bed of the river, was anterior to the existence of volcanoes in the Auvergne, though they have been extinct since the period of authentic history.

fig. 49.



On the coast of Peru, which is a highly volcanic country, Mr. Darwin found pieces of cotton thread, plaited rushes, and Indian corn, imbedded in strata of gravel and sand at a height of eighty feet. At Guadaloupe the sandy beach has been raised and consolidated into a sandstone rock on which was found imbedded a human skeleton; the specimen was brought to this country, and is to be seen in the British Museum. These raised beaches indicate clearly enough that they were at one time on the same level as the sea, and it is sometimes a disputed question whether the land has been raised or the sea depressed. That the land has been, and continues to be subject to elevations and depressions is a fact made known by observations within recent times, and which all geological evidence directly confirms. A depression of the bed of the sea would of course lower the surface level, but in such case the recession of the water would be general, and the sea would not, as it is known to do in our own island, be gaining on the land in one part and be receding in another. This irregularity of effect shows that the cause is to be attributed to the movement of the ground near the shore.

The deposit from the ruins of the hills and mountains spread so extensively and abundantly over the surface of most lands has sometimes been called the "boulder formation;" and its extent, and its importance, as marking a distinct change in the condition of the globe, give it a claim to be considered as something more than as a superficial covering of other strata. The term *diluvial* deposition has been applied to the great masses that were transported from distant mountains whilst the land was under water. Those beds of sand, loam, and marl which have been spread over the surface by the action of rivers and torrents since the land was raised to its present elevation, above the sea, are called *alluvial* deposits, though the terms are sometimes employed indiscriminately to indicate all superficial covering of the regularly stratified formations.

The alluvial deposit is that part of the earth's crust to which geologists pay least attention, yet it is the most important to man, as serving for the growth and nourishment of the plants and vegetables on which he depends directly or indirectly for his sustenance.. Though the examination of the soil and its adaptability to the support of vegetable life pertains to the agricultural chemist rather than to the geologist, yet as those soils are constituted from the ruins of the rocks whose successive formations and elevations have been his study, he cannot look without interest at what may be considered to be the ultimate result and object of all geological changes. When rocks contain in their compositions a due proportion of silex, clay, and lime, they furnish soils whose fertility may be said to be permanent. The most fertile districts in England were made so by Nature.

In the foregoing descriptions of the diluvial deposits we have purposely omitted to notice the accumulations of the bones of hyenas, tigers, elephants, and other animals found in caverns in this and in other countries, because they are altogether superficial and constitute no portion of regular depositions. They are, however, extremely interesting as indications of the character of the inhabitants of the earth at the period immediately before the creation of man, and they will form an important subject for consideration in a subsequent part of this volume when we notice the inhabitants of former worlds.

CHAPTER XII.

VOLCANIC ROCKS.

General character of volcanic rocks.—Basalt; its composition and structure.—Basaltic columns at the Giant's Causeway.—Crystallization of basalt.—Porphyry.—Distinction between it and granite.—Basaltic dikes: their ejection from beneath.—Composition of lava and trachyte: their resemblance to basalt.—Pumice, volcanic tuff, and obsidian.—Other volcanic products.

WE have avoided interrupting the description of the regular succession of stratified beds by noticing the igneous rocks which are interspersed among and frequently overlie them. These rocks constitute important geological features in many countries, where they form ranges of hills or cap the highest mountains; and they are more or less abundant in all parts of the world. They are generally known as "trap," or basaltic rocks, but they assume great varieties of appearance, and undergo changes in structure according to the different circumstances that have attended their fusion and refrigeration. The leading characteristic is their igneous origin. In composition they are nearly allied to the primary rocks; the distinguishing difference being, that they were ejected from under the surface after most of the other beds had been deposited, and they are the newest rocks with which we are acquainted. Though granite forms the foundation on which all other rocks rest, and basalt lies upon the top of all, the two rocks are nevertheless so closely allied that they sometimes blend one into the other.

It is unnecessary to perplex the geological student with particular descriptions and the special names of the various modifications of volcanic rocks, since nothing but close examination of specimens would enable him to distinguish several of these varieties; we shall, therefore, only notice those which are the most important and which present easily distinguished differences.

The chief constituents of all volcanic rocks are felspar and hornblende. The former, it will be remembered, consists principally of silex, alumina, and potass, in the relative proportions of 63, 17, and 13, with a small quantity of lime and a trace of iron; whilst hornblende has, in addition to silex and alumina, greater proportions of oxide of iron and lime, and sixteen per cent. of magnesia. Basalt, the most important of the volcanic rocks, contains a much larger proportionate quantity of alumina than either felspar or hornblende, with less magnesia than the latter, and a nearly equal quantity of oxide of iron. It has a greenish, or brownish-dark colour, is very difficult to break, but is not so hard as to resist the point of a knife. The structure is crystalline, and it melts, at a great heat, into a black glass. The iron in basalt becomes more oxidised by exposure to the air, and it thus acquires a reddish-brown colour on the surface. Basalt frequently occurs in thick beds overlying other rocks, having been thrown over them in a molten state, as if erupted from a volcano. These beds of basalt frequently assume a columnar structure, exhibiting a crystallized arrangement on a large scale, the prisms having sometimes five sides, sometimes six, seven, or eight, and occasionally only three sides.

In the north of Ireland, and in the Hebrides, magnificent basaltic ranges of columns are laid bare on the cliffs of the sea coast. The Giant's Causeway presents one of the most remarkable displays of natural pillars, which may be seen along the coast of Antrim, from Fairhead to the promontory of Bengore, a distance of eight miles. Some of these pillars are one hundred and fifty feet high, and five feet in diameter; but at the part to which the name of the Giant's Causeway is often limited the columns are not so large. The range of basaltic rocks in Antrim extends for a length of forty miles, and occupies a superficial extent of 1000 square miles; the average thickness of the mass being 540 feet. The foundation rock on which this basalt rests varies in different places from chalk to lias and green-sand; and the columns, with their basements in front, attain a height of 1800 feet. This range of basaltic rocks, it is conjectured, passes eastwards under the sea to the Hebrides, where Fingal's Cave, in the Isle of Staffa, is scarcely less celebrated than the Giant's Causeway.

The columnar form is not general in basaltic rocks, and in many parts even of the Giant's Causeway there is no appearance of crystalline arrangement, the basalt being what is termed "amorphous." The crystalline structure of basalt seems to have depended on the circumstances under which it was cooled from a state of fusion. In some experiments conducted by Mr. Gregory Watt, on the fusion and refrigeration of basalt, he succeeded in producing the columnar arrangement.

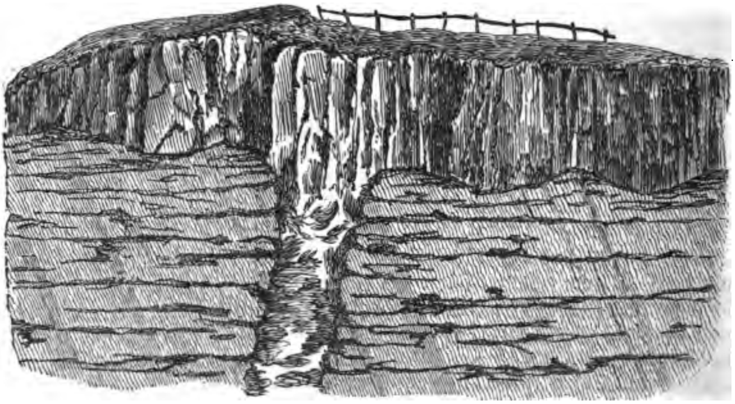
Basalt is deposited on the summits of hills in many parts of England and Scotland; and though it occasionally overlies the transition rocks, it most frequently has been ejected among and over the rocks of the secondary formation. It occurs, indeed, in all parts of Europe; but the most extensive mass of basalt, and of the volcanic rocks closely allied to it, occurs in South America. The general arrangement of the Andes is, according to Humboldt, the same as the Alps up to a height of about 11,000 feet; but over the granite, gneiss, and clay-slate, there are piled up immense masses of basalt and porphyry, that attain a height of 22,000 feet above the sea, and are arranged in regular columns, which, when seen at a distance, appear like the ruins of enormous castles.

The volcanic rocks most closely allied to basalt are clinkstone (so called from its sounding like metal when struck), pitchstone (containing bitumen), greenstone, and wacke, all of which may be considered merely as various modifications of basalt, since they have the same characteristics, nearly the same mineral composition, and a similar structure.

The next distinctive volcanic rock is porphyry. Any compact rock that contains large separate crystals imbedded in it is called a porphyry; but the term is sometimes limited to a small grained dark-coloured granite, containing large distinct crystals of felspar. This kind frequently passes into granite, from which it is principally distinguished by the large felspathic crystals. Another kind of porphyry, called amygdaloid, still more closely connected with volcanic rocks than ordinary porphyries, consists of a base of basaltic rock, with enclosed crystals of quartz. The volcanic origin of the latter rock may be traced in recent lavas, which are sometimes filled with cells, as if gas had been generated and had escaped in bubbles when the mass was partially cooled, and the molten matter not sufficiently liquid to close up the cavities made by the escaping bubbles. In the amygdaloidal rocks, these cells have been filled up by successive depositions of siliceous matter, held in solution by the water that percolated through them.

The foregoing belong to the older class of volcanic rocks, which overlie and are overlaid by the stratified rock formations, and were formed at periods long before any active or known extinct volcanoes. Respecting their igneous origin, though at one time disputed, there is, we believe, no longer any doubt. There are no perceptible craters through which the melted matter has been thrown, but the continuous lava currents can be traced extending downwards to an unknown depth. A section of a basaltic dike, connected with an overlying bed of basalt, is exposed to view in a quarry near Bolam, in Cleveland, described by Professor Sedgwick, and shows clearly that the basalt has been ejected through the limestone from some source of molten matter beneath, which lies too deep to be penetrated.

fig. 50.

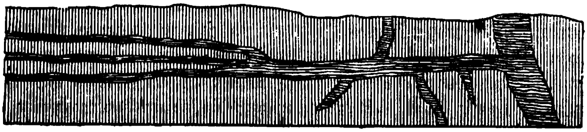


The dislocations in strata which obstruct the operations of miners have been before briefly noticed. They have been occasioned generally by eruptions of volcanic matter through rents in the rocks, which have raised the strata on one side and depressed them on the other. The dikes are most frequently filled with basalt, and its molten state at the time of eruption is apparent in the effects produced on the contiguous strata. When a basaltic dike passes through a seam of coal, the coal is often converted into soot, and at a farther distance it becomes coke, as it would be if acted on by great heat under pressure, and excluded from the atmosphere. Where chalk and limestone have been penetrated by the melted mass, they become indurated, or crystalline; and all other rocks are more or less changed by the heat to which they have been exposed in immediate contact with the basalt. The largest basaltic dike in England is one that extends from the west of Durham, in a waving line through the Cleveland hills in Yorkshire, to the coast between Whitby and Scarborough.

into the sea, and it may be seen on the surface through a great part of that range. The length of this dike is estimated at sixty miles, and in its course it cuts through the carboniferous limestone, the coal measures, and the upper secondary strata. Another extensive basalt dike crosses the county of Durham from Allenheads to Burtreeford, which has thrown down the strata on the west side of it no less than 160 yards.

In some places, basalt is found lying interposed between strata horizontally, resembling a stratified bed of rock; and from this circumstance those geologists who attributed the formation of all rocks to sedimentary depositions concluded that basalt had been deposited from aqueous suspension. A more careful examination of such basaltic beds has, however, tended to confirm the opposite opinion of their igneous origin. The section, figure 51, which represents horizontal basaltic beds in the Isle of Skye, shows clearly that basalt has been forced horizontally through rents made in the rocks, for it terminates in streams at a distance from the dike, to which it can be traced.

fig. 51.



The distinguishing difference between basaltic rocks and the products of recent volcanoes consists in the comparative lightness and porosity of the latter. This difference in texture is attributable to the circumstance that basalt has generally been erupted at the bottom of the sea, under great pressure, and not on the surface, with the pressure of the atmosphere alone upon it.

That basalt was erupted under great pressure may be inferred both from geological and mechanical evidence. In the first place it has been ascertained geologically that the rocks over which it has been thrown were formed under water, and for the most part in a deep sea; and the fact that the rents through which the basalt was ejected are also filled with it, without any breach of continuity, affords evidence of pressure in the superincumbent mass when in a liquid state. Had the basalt been ejected from a crater into the atmosphere, there would have been, as in the case of recent volcanoes, spaces left between the erupted matter and the passage through which it was forced out, caused by a recession of the molten mass when the impelling force became exhausted. But supposing the eruption to have taken place under great pressure, when the impulsive force diminished or ceased to operate, the continuous liquid current, though stopped in its course, would either remain where it was elevated till it became solidified, or, if it receded, the superincumbent melted basalt would be pressed down again and prevent any cavity from being formed between the stream of lava and its deposited bed.

If we include among the older volcanic rocks all those that have been obtruded in a melted state through the superincumbent strata, even granite would have to be placed among the number, for veins of that rock are to be seen at Glen Tilt in Scotland, as before noticed, and in other granitic districts, which have been forced through the adjacent rocks just like dikes of basalt and mineral veins. Granite does not, however, occur overlying other rocks in extensive beds, as we meet with basalt; but porphyry and sienite, which may be considered as different modes of granite, occupy such positions; and it may be inferred with a degree of probability that the eruption through the other rocks and the process of cooling on the surface have changed the mineral structure, and that the sources whence overlying porphyries and sienites are derived might have been molten granite.

The recent volcanic rocks which can be traced directly to the craters of volcanoes, either active or extinct, are composed principally of felspar and a modification of hornblende called augite; the distinction in the proportion of those two minerals constituting the distinctive differences in the products. The solid volcanic rock lava, if it contain a large proportion of augite, becomes dark coloured, and resembles basalt in all respects but in being more porous. When felspar predominates the lava is called "trachyte," the term being derived from τρακυς, because it feels peculiarly rough. Trachyte is of a lighter colour than basaltic lava, is commonly greyish, and varies in its structure from a coarse grained, to a close grained, compact, and crystalline mineral; its hardness varying with its compactness. The lavas of Vesuvius scarcely differ from basalt. They are often porphyritic, and extremely compact, especially in veins called dikes, and are not inferior in hardness and in specific gravity to basalt.

Pumice is a well known volcanic product, of a white colour, and so light that it swims upon water. In chemical composition it does not vary from trachyte, the peculiar fibrous and porous texture having been acquired by some peculiar circumstances attending its fusion and subsequent cooling.

Volcanic tuff, or tufo, is a composite product that occurs abundantly in the neighbourhood of volcanoes. It is formed from the decomposition of trachyte, which crumbles into fine particles, and mingling with fragments of pumice and volcanic ashes constitutes a conglomerated mass that is frequently found on the sides of volcanic mountains, concealing from view the underlying rocks.

In some volcanic districts there occurs a black vitreous substance called obsidian, produced by the melting of lava. Though vitreous in appearance, it possesses none of the translucent properties of glass. It is harder than that material, and strikes fire with steel.

Scarcely any three substances could be more dissimilar in appearance than lava, pumice, and obsidian, the principal products of volcanic eruptions; yet chemical analysis proves that their component parts are nearly the same. When, therefore, we perceive that the same materials can be formed into such different looking minerals, varying greatly also in their degrees of hardness and specific gravities, by merely different arrangements of their particles through the agency of heat, the minuter shades, which, in other cases, scarcely distinguish one kind of volcanic rock from another, seem to be undeserving of notice. All that is essential to be known is, that the mineral is a volcanic product; the varied terms of basalt, greenstone, lava, clinkstone, and several others only expressing modifications of the same substance caused by differences in the fusion and refrigeration.

In addition to the stony products of volcanoes there are some other substances of less abundant occurrence. Sulphur is found in the craters of recent and of extinct volcanoes, encrusting the sides in considerable quantities. It appears to have been emitted in sulphurous vapours and condensed within the craters at times when the volcanoes were in a slumbering state and not emitting sufficient heat to set the sulphur on fire. Sulphurous acid gas is one of the known exhalations of volcanoes, and it is probable that the sulphur inside of craters has been concreted from that source. The sulphur of commerce is obtained almost entirely from Sicily, Italy, and from the extinct volcanoes in the Auvergne.

Iron forms a part of most lavas. It presents itself separately as a volcanic product in the peculiar form of brilliant laminæ, called specular iron, which bears a high polish. Great varieties of minerals are found in the lavas of Vesuvius. "It is an extraordinary fact," observes Sir Charles Lyell, "that in an area of three square miles round Vesuvius a greater number of simple minerals have been found than on any spot of the same dimensions on the surface of the globe."*

CHAPTER XIII.

MINERAL VEINS.

Structure of metallic veins.—Fissures in rocks caused by shrinking.—Intersecting veins of different ages.—Veinstone.—Different metals in the same vein.—The levels at which different metals are found.—Affinities of metals for specific rocks.—Gold found near the surface.—Theories of metallic veins—Werner's, Hutton's, and the thermal-water theories.—Probable effect of sublimation.

In the preceding descriptions of the rocks that constitute the earth's crust no notice has been taken of any of the metals, with the exception of iron. None of the other metals can be considered to constitute parts of rock formations, for they are merely interspersed in irregular veins through the substance of the beds wherein they are found. These veins are fissures, or cracks, in the rocks, of various widths, from a few inches to several feet; extending laterally for considerable but very irregular distances, and vertically they generally reach as far as it has been hitherto possible to trace them. The fissures are supposed to be natural cleavages in the rocks, occasioned by their shrinking when cooling from a melted or greatly heated state, and to have been afterwards filled with metallic ores and other minerals.

It might be supposed that if the fissures in the rocks were produced merely by their shrinking, the metallic veins would be generally distributed through all the cleavages, and be limited in continuity of direction to each separate bed. But instead of being thus scattered and broken into divisions, they continue through several different rocks, and generally observe, in England at least, a direction from east to west. This is so common that those veins which traverse in opposite directions are called by the miners "cross courses," and are seldom very productive.

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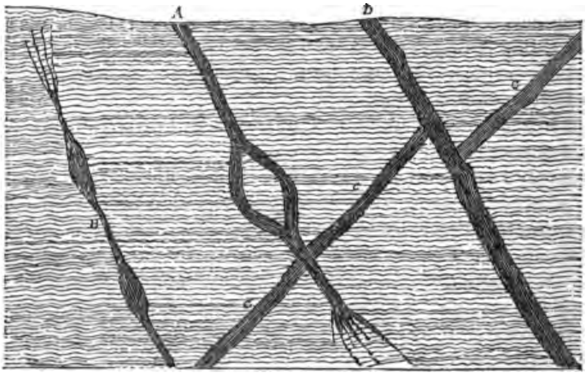
* Principles of Geology.

Veins, when they run in different directions, frequently cut through one another, and at the points of intersection the beds are generally disturbed and lifted up on one side, in the same manner as when a basaltic dike has been forced through them. In figure 52, D, C, C, represent two metallic veins intersecting each other and disturbing the strata at their junction. In this case the vein D seems to have divided the vein C, C, which is raised on the side over which the intersecting vein inclines, as it would be if separated by a fault. The effect in such cases is, indeed, most probably to be attributed to previous disturbances of the strata which have caused rents in the rocks, that have been subsequently filled with metallic ore or other mineral matter.

fig. 52.



The ore is not deposited in veins directly against the rocks they traverse. There is always a lining, or veinstone, as the miners call it, to the vein to form a matrix for the ore. These linings are not exclusively peculiar to the rocks nor to the metals, but they seem to be affected by the conditions of both. Frequently layers of clay occur on each side the ore, which is often intermingled with the veinstone. From the structure of many veins, it seems as if the ore and the veinstone had been deposited at successive intervals one upon the other. In the course of a vein that traverses different kinds of rock, not only does the lining change, but the contents sometimes change from one metal to another, at different depths. Iron, copper, cobalt, and silver ores, succeed each other in the same veins in some of the mines in Saxony; and in France there are mines in which copper appears at the lowest point of the vein, with silver above it, and iron ore on the top. In the copper mines of Cornwall, zinc and copper frequently occur in the same vein, the zinc being uppermost and generally extending but a short depth; tin also is sometimes found in the upper parts of veins which contain copper lower down; and in instances of rare occurrence, after working through the tin into the copper, tin again occurs, and continues to the lowest parts of the mine.

When veins of tin and copper intersect, the copper usually cuts through the tin, from which it may be assumed that tin was, in such cases, an older formation than the copper. It cannot, however, be stated as a general fact, that tin is an older metal than copper, for they sometimes occur together in the same vein. There is, indeed, little certainty respecting the relative ages of metals, and, in some instances, veins of similar metals intersect each other. Sometimes veins "belly out," as it is called by miners; and in other parts they divide and meet again as represented at A and B in fig. 52. Nearly all the metals, with the exception of iron, are limited in range to the primary and transition rocks; those which have been either fused, or subjected to great heat after having been deposited from aqueous suspension. It would appear, therefore, that intense heat has been a necessary condition in the formation of metallic veins.

Though all the metals are found in the rocks underlying the secondary formation, some metals appear to have a greater affinity to peculiar rocks, and are scarcely found in any other in sufficient abundance to be worked. Gold and silver are found in quartz, gneiss, porphyry, sienite, and slate. Gold is also found in the sands of rivers, where it has been washed down from its depositories in the primary rocks. Silver is frequently associated with lead, which abounds most in the carboniferous limestone. Tin is almost confined to granite, and is seldom worked in other parts of England than in Cornwall, where it has been obtained since the earliest records of English history.

The gold in Australia and California occurs in quartz veins, and the large quantities procured from those districts have been hitherto obtained on the surface, or not far beneath it. It is the opinion of miners, in which some eminent geologists agree, that gold is not to be found at great depths, and that when the quantity scattered near the surface has been collected, the source of supply will be exhausted.

The formation of mineral veins has afforded matter for much speculation, nor are geologists as yet agreed respecting the mode by which the fissures were made in the rocks, and the manner of their being filled with metallic ores and other minerals. It was the opinion of Werner—who attributed all rock formations either to mechanical subsidence from aqueous suspension, or to chemical deposition from solutions—that mineral veins were natural fissures in the rocks, which were subsequently filled by deposition. This hypothesis, which held its ground for a long time, was combated by the opposite one, maintained by Hutton, that all veins were filled with melted matter ejected from below, and that in many cases the force with which the molten fluid was ejected formed the passages in the rocks in which the metallic substances are found.

Valid objections can be urged against both these hypotheses. If the minerals had been deposited from solution, and the fissures had been filled from above, it is reasonable to suppose that the metallic ores would have been deposited on the surface as well as in the cracks of rocks; and that all fissures, however small their extent, if opening to the surface, would have been filled with metallic matter, instead of the veins being limited, as is generally the case, to fissures that penetrate to untraceable depths. There are also undeniable evidences of the action of heat in the separation of the less oxidisable metals, so that even allowing deposition to have been the principal source whence the veins were filled, there are many facts connected with the condition of mineral substances, which indicate clearly the subsequent agency of heat.

Veins sometimes terminate upwards in thin streams, (represented at B in figure 52), which do not reach the surface, but widen as they descend. It seems difficult to reconcile such a formation with the hypothesis that the veins were filled from above. It sometimes, though rarely, happens, on the other hand, that the veins contract as they descend from the surface, and terminate in streams, as shown at A in the same diagram. It is equally difficult to reconcile that structure with Hutton's hypothesis, that veins were all filled from below. The occurrence of different metallic substances in different parts of the same vein is opposed alike to either of those hypotheses.

Neither the Wernerian nor the Huttonian theories will account for all the observed phenomena of mineral veins, and the hypothesis now in favour with geologists is, that the mineral contents of veins were held in solution in thermal waters injected from below, and that they were deposited by chemical or voltaic action. Thermal waters, it is well known, frequently contain large quantities of mineral matter, and the filling up of cavities in rocks by calcareous substances is an occurrence that is now daily taking place. Silica, too, is often found in a state of chemical change that admits of its solution in water, and by this means the veins of quartz, of calcareous spar, and other earths in a crystalline form, might have been deposited. From experiments that have been made to ascertain the power of voltaic electricity in eliminating crystals, and even precious gems from earthy solutions, there can be no doubt that voltaic agency might assist the deposition of minerals as well as of metals from aqueous solution, if we admit that a sufficiently active voltaic current could be formed by the contiguity of the different metals contained in rocks. The observations and experiments made by Mr. Henwood in Cornwall, tend to prove that voltaic currents are active in the metallic veins in that district; and if we suppose the rocks to have been submerged at the time of the formation of those veins, there might have been a continuous flow of thermal mineral water through the fissures in the rocks which would mingle with the sea water on issuing from the cavities, and thus prevent any deposition of mineral matter over the surface. It must be observed, however, that the mineral waters at present known contain scarcely any metallic substance excepting iron.

Another source whence the mineral veins might have been filled has not received sufficient consideration. If it be admitted that those rocks wherein metallic veins most abound were at one period in a state of fusion, at a heat greatly exceeding that of the fusing point of metals, it is highly probable that long after the outer crust of the globe had become solidified, mineral and metallic vapours permeated the fissures in the rocks, and condensed on their sides, assuming different forms, and depositing themselves in separate parts, according to the circumstances of condensation and the nature of the fissures through which the vapours passed.

If we assume these mineral vapours to have issued from the fused mass beneath, they would not enter into other fissures than those through which there was a passage to the surface; and during condensation each metal would have a tendency to be deposited at separate levels, and in association with distinctive rocks. It may be observed, also, in support of this hypothesis, that those metals which have the least affinity for oxygen, such as gold, platinum, silver, copper, and tin, would be most likely to be found in a state of purity, and those are the only metals which occur free from combination with oxygen or other substances.

It will be observed from the foregoing statement of the different opinions that have been and are entertained respecting the formation of metallic veins, that the question is still open to discussion. It seems probable that in this, as in many other geological theories, several of the assigned causes have operated at different times; that whilst the deposition from solution in thermal waters may in many cases have filled, or partially filled, fissures in rocks with mineral substances, the metals and metallic ores may have been injected or condensed from the vapour of fused masses situated at great depths below the surface.

CHAPTER XIV.

VOLCANOES, EARTHQUAKES, AND HOT SPRINGS.

Extinct and active volcanoes.—Volcanic craters.—Etna and its many craters—Great eruption of 1669.—Movement of lava.—Volcanoes near Naples.—Destruction of Herculaneum and Pompeii.—Present crater of Vesuvius.—Elevation of volcanic islands and mountains.—Earthquake phenomena.—The great earthquake at Lisbon.—Earthquake in Calabria.—Hot springs.—The Geysers of Iceland: their formation and action.—Theories of volcanoes.—Geographical ranges of volcanoes and earthquakes.

The eruption of molten matter, hot ashes, and masses of rock, accompanied by smoke, vapours, and lightning, from the summits of high mountains, and sometimes from rents in their sides—the flow of hot springs and the ejection of boiling water, and convulsions of the earth that destroy and swallow up cities and mountains—are the most striking phenomena connected with the physical condition of the globe in operation at the present day; and they clearly point to the continued action beneath the surface of powerful agencies capable of producing important changes on the solid crust of the globe. The phenomena of volcanoes are especially interesting to the geologist, since they serve to prove the agency of heat in the formation of rocks, and to point most clearly to the mode by which extensive ranges of rocks, destitute of organic remains, have been superposed on strata of geologically recent age. Having this clue to guide him, the geologist can distinguish, by their conical forms and hollowed summits, extinct volcanoes in various parts of the world where volcanic action has been dormant for ages before the creation of man, and he is no longer at a loss to account for the occurrence of igneous rocks resting upon and intermingling with tertiary strata.

Modern volcanoes are generally situated near the sea, their summits are usually conical, bearing the appearance of having been formed by the depositions of volcanic ashes ejected from the orifices at the top, called craters. These craters are of prodigious size, being sometimes upwards of three miles in circumference. Internally, the sides are steep, sloping down regularly. The bottom part of the craters, when not in a state of activity, is solid, and there are several small cones within, from which volumes of smoke and vapour frequently issue. In volcanic mountains of a great height the eruptions of liquid lava seldom take place from the principal crater at the summit, but the molten matter issues either from rents in the sides of the mountain, or from smaller craters formed at lower elevations.

The principal active volcanoes in Europe are Etna, Vesuvius, and Stromboli, in the extreme south, and Hecla and other surrounding mountains in Iceland, in the north.

The eruptions of Etna are noticed among the earliest historical records. It is stated by Diodorus Siculus, that before the Trojan war, 1200 years before the birth of Christ, the inhabitants of Sicily were compelled to desert a great part of the island in consequence of the destruction caused by an eruption of Etna; and between the colonization of Sicily by the Greeks, and the commencement of the Peloponesian war, in the year 431 B. C., three destructive eruptions occurred. Etna itself is, indeed, the historian of its own antiquity, its age being impressed in imperishable characters by fossil shells of extinct species imbedded in the layers of its successive lava currents.

The mountain of Etna rises above the sea in a magnificent cone, 11,000 feet high, and its grand proportions are not diminished by any surrounding eminences. The base, which is almost circular, is eighty-seven miles in circumference. The whole mass is composed of volcanic matter, which, from the porosity of its structure, has evidently been erupted above or near to the surface. The mountain is divided naturally into three distinct regions. The lowest one is richly cultivated with vineyards, olives, fruit trees, corn, and aromatic herbs, and extends to a height of 2500 feet. Then the temperate zone commences, and forms a belt round the mountain, covered with forest trees, which extends to the height of 6280 feet. At that elevation the frigid zone begins, which is entirely barren, and is for the most part covered with eternal snows. From the circle of snow near the top, the steep conical crater rises, covered with scoriæ and sand, to a height of 1100 feet. A multitude of minor cones are distributed over the flanks of the mountain, which are most abundant in the woody region. There are about eighty of these secondary volcanoes of considerable dimensions.

The accompanying view of the interior of the great crater of Etna is reduced from a drawing in Lieut.-General Cockburn's "Sicily and the Lipari Islands."*

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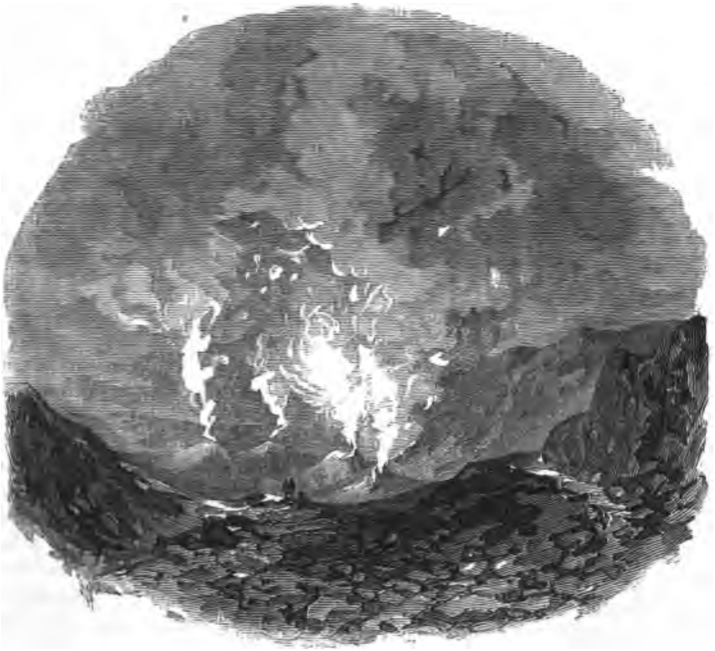
* Lieutenant-General Cockburn ascended the mountain in the middle of the month of November, and gives the following description of the scene and of the difficulties of the ascent:—"On arriving at the foot of the cone of the great crater, having ridden the last three miles through snow, we found Jemelara's house buried in it, just enough of the top visible to show there was a house there; breakfast was, therefore, out of the question. It was impossible to ride farther, so here we left the mules, and proceeded on foot for a mile through snow and over slippery rocks of lava. There are enormous masses of lava, and the space between them, in many parts, so deep that, summer or winter, you must take a long step from one to the other; in other parts, we often sunk to our middles in snow. We at last got over this terrible passage, and arrived at the bottom of the steep cone. This part is all covered with cinders and ashes, but from the heat of the volcano there is no snow at present. Here the difficulty of ascending, and

The first great eruption of Etna of which there is a distinct record took place in 1669. The symptoms of an approaching eruption are usually an increase in the smoke, which sometimes rises to a great height, branching out in the form of the pine trees that grow on the sides of the mountain. Loud explosions, like the firing of cannon, are heard after the increase of the smoke, and are succeeded by showers of stones ejected from the crater. For several months before the great eruption of 1669, the crater at the summit of Etna was observed to send forth quantities of smoke and flame; the cone of the crater had fallen in, so that the mountain was considerably lowered, and the volcanic islands of

fig. 53.



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the labour and fatigue, are very great. The air is so pure and rarefied that it affects the lungs, and we lost our breath every five minutes. We were obliged often to scramble on all fours, slipping down frequently many feet in the loose ashes. I was the first of our party to reach the summit, and gave three cheers. The sudden view of this immense gulph is terrific at first, and really past description. We saw most distinctly to the bottom of this wonderful and immense crater, which contains several minor mountains and their craters within it; some smoking like the most violent glass-house or steam works. The ground was here very hot. A descent into the crater, if the ground is as hard as it appears to be, would have been this day perfectly practicable, but our time did not admit of the experiment. The crater often changes its form: on the side which we first approached the descent was perpendicular, but the opposite side went down by a gradual slope. On stirring the loose ashes, the smoke comes out, and the ground feels very hot; if scraped a little, so much as to burn. On this steep part I lay flat and put my head over the precipice, and took some hot minerals out of the crater."

Stromboli and Volcano, to the north of Sicily, were observed to rage more than usual. Eighteen days before the eruption the sky was very lowering and dark, with thunder and lightning, frequent concussions of the earth, and dreadful subterranean noises. An earthquake levelled to the ground all the houses in Nicolosi, a town situated about twenty miles from the summit, and ten from the sea at Catania. Two rents opened near Nicolosi, from which sand and scoriæ were thrown in such quantities that in the course of three or four months a double cone was formed, called Monti Rossi, about 450 feet high. A fissure six feet broad, and of unknown depth, opened with a loud crash, and extended in a tortuous course to within a mile of the great crater, for a distance of twelve miles. It emitted a most vivid light. Five other fissures, parallel to the first, afterwards opened, one after the other, and emitted smoke and produced bellowing sounds that were heard at the distance of forty miles. The great rent that was first opened appeared to be filled up with molten matter, and a crater opened near Monti Rossi, which poured out a prodigious current of lava. The lava, after overflowing fourteen towns and villages, arrived at the walls of Catani, which had been purposely raised to protect the city. The molten current, however, accumulated till it rose to the top of the wall, which was sixty feet high, and then fell over it in a fiery cascade, and destroyed a great many houses. The wall, however, resisted the pressure of the molten mass against it, and was long afterwards discovered imbedded perpendicularly in solid lava, which may now be seen curling over the top of the rampart as if it were arrested in falling. The current of lava thrown out during this eruption covered an extent of eighty-four square miles, and the number of cubic yards was estimated to be 140,000,000.

The district round Naples has been celebrated for its subterranean fires by historians and poets from the remotest ages of antiquity. Volcanic eruptions are mentioned by early historians as having driven the inhabitants from the island of Ischia, 300 years before the Christian era, but no notice was taken of Vesuvius, which is now the principal centre of volcanic action, until the year 79 A.D. Before that period the sides of the crater of the seemingly extinct volcano were grown over with trees and there was a sterile plain in the centre. During the insurrection raised by Spartacus and the Gladiators, B.C. 71, in the commencement of their insurrection they took refuge in the crater of Vesuvius, which afforded them a secure retreat. At that time the cone was of a very regular form, terminating with a flattish summit, and the ancient crater was nearly filled up. On the exterior, the mountain was covered with fertile fields richly cultivated. At its base were the populous cities of Herculaneum and Pompeii; the former situated at a distance of about five miles from Naples, and Pompeii seven miles farther. An earthquake in the year A.D. 63 did considerable damage to those cities, and from that time slight shocks continued till the month of August, 79, when they became more severe, and the first recorded eruption took place on the 24th of that month.

The elder Pliny, who commanded the Roman fleet at Misenum, went on shore to have a nearer view of the phenomenon, but the shower of ashes was so thick that he was compelled to retreat under cover. On the following day, when he attempted to ascend the mountain, he was suffocated by the sulphurous fumes, and his nephew, the younger Pliny, who remained in his ship, saw him fall. During this eruption, a dense volume of vapour was first observed rising vertically from Vesuvius, and then spreading itself out laterally, like the branches of a pine tree. Through this black cloud were seen flashes of fire as vivid as lightning, succeeded by profound darkness. Ashes fell as far as the ships at Misenum, and caused a shoal in one part of the sea; the ground rocked and the sea receded from the shore, and many marine animals were left on the sand.*

Vesuvius is a small mountain compared with Etna, therefore it is more liable to be altered by the eruption of large masses of matter from its crater; and there is reason to suppose that at the period of the great eruption of 79, Vesuvius was considerably higher than at present. Great alterations in the size and form of the crater have, indeed, taken place within the last forty years. The great crater, until the year 1822, had been gradually filling up by the rising of lava from below and the scoriæ from numerous small eruptions, so that it resembled a rough plane intersected with fissures from which vapours were emitted. In 1822 there was a succession of explosions, which lasted twenty days, during which not only was the accumulated material ejected, but a large portion of the cone of the crater was carried away, so that the mountain was lowered from a height of 4200 feet to 3400 feet. A gulf was left after this eruption 1000 feet deep and three-quarters of a mile across in its longest diameter.

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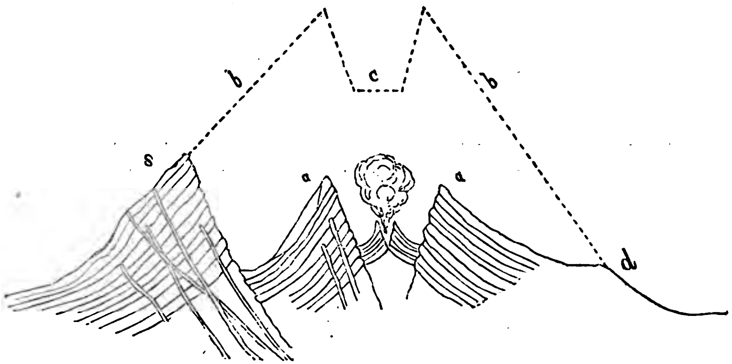
* Of the fate of Herculaneum and Pompeii, which were buried during this eruption, no mention is made by Pliny, who fully describes the active phenomena of the volcano; and those cities were so vaguely noticed by other historians, that the accounts of their existence and destruction were supposed to have been fabulous, until they were accidentally discovered in the beginning of the last century. More than one-fourth of the city of Pompeii is now cleared out, and it is ascertained that the walls of that ancient city were three miles in circumference. The state of preservation in which the things are found is very remarkable. Even manuscripts preserve their forms, and have been partially deciphered; writing on the walls, and the names of the occupiers of each house, written over the doors, are distinctly legible, and the colours of fresco paintings in the interior of buildings are as fresh as if recently painted.

One of the curious facts revealed by these excavations is, that at the time the cities were buried under showers of volcanic ashes, the inhabitants were engaged in repairing the damages done by the earthquake which occurred sixteen years before. Inscriptions on temples, both in Herculaneum and Pompeii, announce that they had been rebuilt after the earthquake. The walls of the houses in Pompeii are in many places rent open, and columns are lying on the ground, only half hewn, intended for temples that had been partially repaired. The pavement is in general undisturbed, and consists of flags of lava hewn from currents that had in ages previously flowed from Vesuvius; and two deep ruts, worn by the passage of carriages, are curious indications of the great carriage traffic through the narrow streets. The small number of skeletons, and the few intrinsically valuable portable articles that have been found, prove that the destruction of the cities was not sudden, but that the inhabitants had had time to escape and carry with them their most valuable treasures. In the buildings for the soldiers at Pompeii were the skeletons of two men chained, and in the vaults of a house in the suburbs were found the skeletons of seventeen persons, who it may be supposed had fled there to escape from the showers of ashes, and were either suffocated or overwhelmed. The material in which they were imbedded was indurated tuff, and the form of a woman with a child in her arms was imprinted distinctly in the mass. On the skeleton of the woman was found a gold chain, and rings set with jewels were on the finger bones.

Among the interesting relics which show the condition and civilization of the inhabitants, and the state of preservation of perishable articles, may be mentioned public fountains decorated with shells; a collection of shells, arranged in the room of an artist, comprising a great variety of Mediterranean species, in perfect preservation; fishing nets were abundant; and in a fruiterer's shop in Herculaneum were vessels full of almonds, chesnuts, and walnuts. A carbonized loaf was found in a baker's shop with his name stamped upon it, "Eleris Q. Crani Riser," and on an apothecary's counter were a box of pills and a cylindrical roll, evidently intended to be divided into pills.

Mount Somma, which is now a separate mountain, is conjectured to have at one time formed part of the original cone of Vesuvius. The diagram, fig. 54, represents a section of the crater of Vesuvius and of Somma, and shows the alteration which Sir Charles Lyell supposes to have been effected in it by the earliest known eruption. The cone *s* represents Somma, which is now distinct from Vesuvius; and *a*, *a*, the great crater left by the eruption of 1822, within which is the small cone thrown up in 1828. There is a terrace, *d*, encircling the base of the present cone on the south side, and the dotted lines mark the supposed form of the cone of Vesuvius before that side was thrown down. In the opinion of the distinguished geologist Von Buch, however, Somma was elevated by subterranean force, and is distinct from the ancient crater of Vesuvius.

fig. 54.

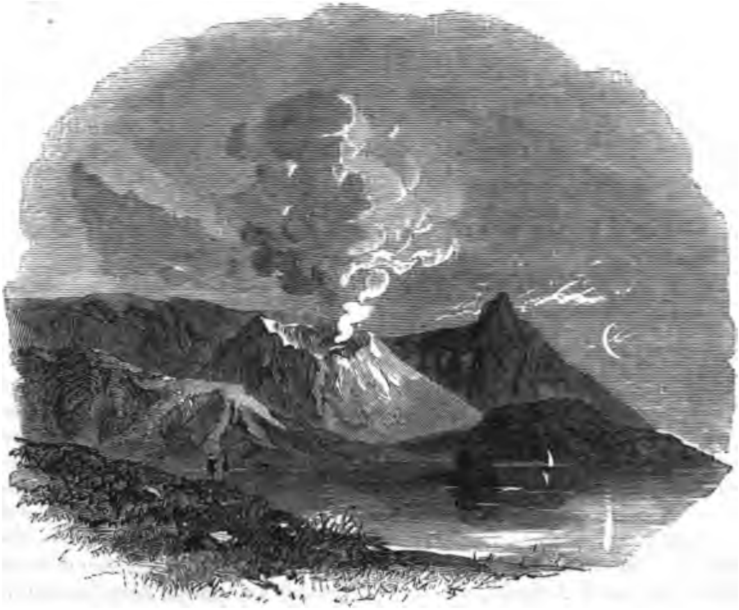


The physical phenomena attending the eruptions of all volcanoes are nearly the same as those we have described to have occurred during the great eruption of Etna, though the matter ejected varies in character and in quantity. Scoriæ, and what are called ashes, and sand, are only different forms of lava, which is altered in condition by the circumstances of its eruption; for the sudden explosions disperse the liquid matter into the air and disseminate it into small particles. Molten lava is seldom if ever ejected in a mass far above the brim of the crater, and most frequently its pressure bursts through the sides of the mountain before rising to the crater at the summit.

Occasionally volcanoes break out under the sea, and eject volumes of ashes and lava sufficient to rise to the surface and form islands. The Lipari islands to the north of Sicily are all volcanic, and present the appearance of having been raised from the bed of the sea. The most remarkable of these are Stromboli and Volcano. The volcano of Stromboli, represented in the frontispiece, has been in a continued state of activity for many centuries, and accounts of its eruptions are given by ancient historians three hundred years before the Christian era. It produces no flow of lava, but at intervals of about ten minutes throws up quantities of stones and ashes, the greater part of which fall back again into the crater.*

The island of Volcano, which lies a few miles south of Stromboli, is also in an active state. For the accompanying sketch, taken from the hill near the ancient baths at Lipari, we are indebted to Lieut.-General Cockburn's work before quoted.

fig. 55.



Before the great eruption in Iceland in 1783, which continued almos without intermission for six years, a submarine volcano burst forth thirty miles from the island, and ejected so much pumice that the water was covered with it to a distance of 150 miles. An island with precipitous cliffs was elevated from the sea, and emitted fire, smoke, and pumice.

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* Lieutenant-General Cockburn gives the following account of his visit to the island, in February, 1811:—" We arrived at Stromboli by moonlight, but stood round the island in order to see the volcano. We came opposite and just under it, and laid to near an hour to look at it. There was a great smoke and a furious fire. About every ten minutes the mountain grumbled, and a small eruption took place, which, for its beauty and singularity, amply repaid the trouble of the voyage."

On the following morning he ascended :—"The mountain of Stromboli is very steep. The day was hot, and the ascent very difficult ; far more so than Etna. I was often obliged to rest, but determined not to give up if I could only get three yards at a time. Some places are very rough, and have large loose rocks and scoriæ, which add to the

This island was claimed by the King of Denmark, who called it Nyöe, or the new island, but within a year of its appearance this addition to the kingdom of Denmark descended into the ocean, and a reef of sunken rocks was the only indication where it had been.

Nor are these phenomena confined to the sea. Sometimes, in volcanic countries, high hills are raised up in a few hours from plains. The most remarkable instance of this kind, of which there is a distinct record, was the elevation of Monte Nuovo, near the Bay of Baiæ, in the Phlegrean fields. After premonitory symptoms of two years, during which frequent earthquakes disturbed the neighbourhood of Puzzuoli, on the 28th of September, 1538, the earthquakes rapidly increased in violence and number, and in the night of the 29th a gulph opened, and a large fissure approached the town, with a terrific noise, and began to discharge pumice-stones, blocks of unmelted lava and ashes, mixed with water, and occasionally flames. The sea retired suddenly for two hundred yards, and a portion of its bed was left dry. On the 3rd of October the eruption ceased, after having raised up the hill now known as Monte Nuovo, which has a deep crater in the middle. The height of the hill is 440 feet above the level of the bay, its base is about a mile and a half in circumference, and the depth of the crater is nearly equal to the height of the hill. The whole neighbourhood is highly volcanic, and the hill stands partly on the site of a lake which was the crater of an extinct volcano.

In various parts of the world the evidence of volcanic action is very apparent, and volcanoes, either dormant or active, are found associated in connected links, which have been termed volcanic bands. An extensive band of this kind stretches in the shape of a horse-shoe nearly across the Pacific, including Sumatra, Java, and New Guinea, and thence extending northwards to the Philippine Islands. A similar band extends through the Greek Islands from Poros in the north-west to Santorin in the south-east. A range of active or dormant volcanoes passes from the southern extremity of the American continent to the northern, along a line of 6000 miles, including some of the loftiest mountains in the world, among which the volcano of Popocatapetl, in Mexico, pours lava from its summit 17,000 feet above the level of the sea. In Kamschatka, Greenland, and Iceland, among perpetual ice, these fiery mountains abound; in the Canary Islands, the Peak of Teneriff sends forth its column of smoke; in the Azores, in the West India Islands, and in the Islands of the Indian Sea, there are volcanoes active or dormant; and though little is known of the geology of Asia and Africa, that little is sufficient to show that in those continents volcanic action has also been in extensive operation.

difficulty; and in other places the loose cinders are so steep, that out of five steps three are lost. It took us more than three hours to get to the top of Stromboli. The crater is lower down on the side of the mountain, and people go to the top in order to look down upon it. There are two craters, but small, and every ten minutes, or quarter of an hour, there is an eruption, with a grumbling noise like thunder, from the largest. At one time the wind cleared away the smoke for a few minutes, and I distinctly saw into the craters; one had positively the appearance which I was desired to remark—viz., the volcanic matter seemed red hot, as if boiling in a large pan, and the moment it rose to the top an eruption took place." In the evening the adventurous traveller attempted to climb the mountain from the side facing the sea, but after being twice struck by the showers of stones, he was glad to effect a retreat to his boat.

Volcanoes are generally preceded by convulsive movements of the ground, accompanied by loud subterranean noises. When the lava finds vent the convulsions usually cease, and the more striking effects of the fiery eruption make the premonitory earthquakes seem to be merely accessory occurrences. It seems, however, from the cessation of earthquakes when volcanoes burst forth, as if the pent up internal forces found vent through these openings; and that instead of regarding earthquakes as accompanying incidents of volcanoes, they should be considered as the primary phenomena of which volcanoes are only the results.

In historical records, earthquakes have precedence to volcanoes. A very complete "Catalogue of Recorded Earthquakes from 1606 B.C. to A.D. 1850," has been compiled with great industry by Mr. R. Mallett, at the request of the British Association for the Advancement of Science, the first part of which has been published in their proceedings. From this catalogue it appears that upwards of 1900 earthquakes have been recorded from the earliest times down to the great earthquake of Lisbon, in 1755; and of course numerous others must have occurred, especially in ancient times, of which no record remains.

It has been remarked that earthquakes are generally preceded by a long continued drought, and that for a few days before any shock is felt, the sun looks red, meteors and the aurora borealis are more frequent, the barometer generally falls suddenly, and a sensation of dread pervades most animals, which is perceived in their looks, and by the utterance of cries of fear; and in man the sensation of sea-sickness has been experienced.

Earthquakes are far more destructive in their effects than the most violent volcanic eruptions; and though the latter present the most imposing appearance to the eye, the sensation of awe and dread must be far greater during the visitation of a violent earthquake. Imagine, for instance, the inhabitants of a city roused from their slumbers by loud subterranean noises like the discharge of artillery, and before they have recovered from their consternation, to feel the ground trembling under them, to see all moveable things thrown down, and the walls of the houses tottering and falling. They rush into the street to avoid the danger, but they can no longer maintain their footing; they are thrown on the ground, where they lie appalled by the sound of falling houses and the shrieks of the sufferers, and are half suffocated with dust. If they seek for refuge near the sea-shore, an immense wave comes roaring in, threatening to sweep all before it; or perhaps, what is still more dreadful, the earth opens with a deafening sound, and swallows up every thing within range of the yawning gulf.

The destruction of life and property that occurred in remote periods of history exceeded that of the great earthquake at Lisbon, in 1755, which is referred to as the climax of convulsions in modern times. Asia Minor and Constantinople were frequently desolated; in India, in 893, an earthquake destroyed 180,000 persons; at Tabriz, in Persia, 50,000 were killed by an earthquake in 1040; and in 1727 another earthquake in the same city destroyed 77,000. Calabria and Sicily have often suffered most severely. China also has been many times visited with earthquakes, and during one which occurred in 1731, 100,000 persons were killed in the city of Pekin alone, and a much larger number were destroyed in the surrounding country.

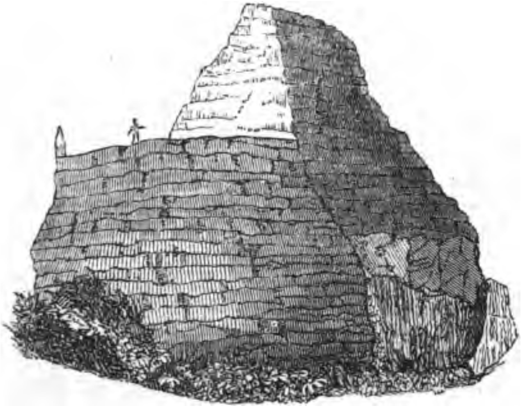
The island of Jamaica has been several times remarkably convulsed; the ground heaving and opening in a more violent manner than has been noticed during earthquakes in other places. In 1692, an earthquake happened which in two minutes destroyed the town of Port Royal, at that time the capital of the island, and sunk the houses in a gulf forty fathoms deep. In many places the earth opened and closed again, and continued this agitation for a considerable time. In some of these openings the people were swallowed up at once; in others, the earth caught them by the middle and crushed them to death; whilst others, more fortunate, were swallowed up in one chasm and thrown out alive from another.

The great earthquake at Lisbon commenced on the 1st of November, 1755. The day before, the sun was obscured by a remarkable gloom in the atmosphere. Early in the morning of the fatal day, a thick fog arose, which was soon dissipated by the heat of the sun. No wind was stirring, the sea was calm, and the temperature about 70°. At thirty-five minutes past nine, after a sound as of thunder underground, the earth shook with short but quick vibrations, which threw down many houses. After a momentary pause, the direction of the motion was changed, and the houses were tossed from side to side. This second shock laid almost the whole city in ruins, and destroyed 60,000 of the inhabitants within six minutes. The most extraordinary incident during the shock was the sinking down of a new quay built entirely of marble. A great concourse of people had collected there for safety, but suddenly the quay sank with all the people on it, and not one of the dead bodies ever floated to the surface. A number of boats that were anchored near the quay, all filled with people, were swallowed up as if in a whirlpool. No fragment of these wrecks ever appeared, and the water on the spot where the quay formerly stood is 100 fathoms deep. The sea came in three times to an extraordinary height, each wave succeeding a shock. It continued ebbing and flowing in great agitation the whole day and next night.

Besides Lisbon, which was utterly ruined with the loss of 12,000 houses, most of the towns and villages of Portugal experienced more or less damage, though Oporto escaped uninjured. The earthquake was also felt very severely on the northern coast of Africa. Near Morocco a mountain opened and swallowed up a village with 8000 or 10,000 people, and soon afterwards closed over them. In Spain the shocks were very severe, and the greater part of Europe felt their effects; even in the West Indies there were oscillations of the ground. Nor were the convulsions of the earth limited to the first day. For many days during the month of November and December severe shocks continued; and one, on the 8th of November, threw down some of the houses in Lisbon that had withstood the former shocks.

Calabria has been a severe and very frequent sufferer from earthquakes, but all previous ones were surpassed in importance by that which commenced in 1783, and was renewed at intervals for four years. During that time the phenomena of the shocks were carefully noted by several scientific persons, some of whom were deputed by the king, and by the Royal Academy of Naples, to examine the facts and record their observations. The first shock, felt on the 5th of February, 1783, threw down in two minutes the greater part of all the towns and villages from the western flanks of the Apennines in Calabria to Messina. Another occurred on the 8th of March, of nearly equal violence. The effect was but little felt in the chain of granite mountains which range from north to south of Calabria, and seems to have been confined to the recent strata resting upon them. The shocks are stated to have been propagated with a wave-like motion from east to west, and to have been most violent at the junction with the granite. The effects of the earthquake in altering the level of the ground in places where fissures occurred were carefully noted and drawings taken, from which it appears that the ground was sometimes on the same level on both sides of new ravines, but sometimes there had been a considerable elevation or depression. In some cases the strata had shifted their positions to the extent of ten feet. The most remarkable instances occurred in the town of Terranova, where a large circular tower of solid masonry, which had withstood the shock, was divided by a vertical rent, and one side was raised and the foundations heaved out of the ground, as shown in fig. 56. On each side the walls were found to adhere firmly to each other, so that the only sign of their having been disunited was the want of correspondence in the courses of stone. In this effect a close resemblance is perceptible to a fault or slip in the strata, so often met with by miners.*

fig. 56.



Hot springs may be regarded as intimately connected with volcanic phenomena. They generally occur along ranges of volcanoes, either active or extinct, or in places where the disturbances of the strata give proofs of internal igneous action. The principal hot springs in England are those of Bath, Bristol, Buxton, and Matlock. The waters in those places have maintained for a long period nearly uniform temperatures, which circumstance indicates that the cause of heat is deeply seated, though most probably the temperature of the water is considerably diminished as it approaches the surface. The temperature of the Bath thermal springs is 112°, that of Bristol 80°, of Matlock 66°, and of Buxton 82°, whilst the waters at Aix-la-Chapelle and Carlsbad are respectively 143° and 165°.

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* Though Great Britain has hitherto possessed a happy immunity from the terrible effects of earthquakes, they have been by no means uncommon in different parts of the kingdom. In Mr. Mallett's "Catalogue of Recorded Earthquakes," England is often mentioned as the seat of their visitations since the year 1275, which is the first one noted; but the recorded phenomena are ludicrously insignificant when contrasted with the destructive effects in other places. Whilst in other countries in Europe and throughout the world the visitations of earthquakes are accompanied by the destruction of cities and their inhabitants, earthquakes in England have been of the most harmless kind. With the exception of the first one, in 1275, in which "many of the most famous churches

In Iceland, where the springs acquire a boiling temperature, they exhibit some features remarkably analogous to the eruptions of volcanoes. Professor Bunsen, who recently paid a visit to that island, has thrown great additional light on the phenomena of the eruptive boiling springs called geysers, and has afforded a new and very satisfactory explanation of their formation and causes of action, which may be applied also to the explanation of many volcanic phenomena.

In Iceland the land rises gradually from the coast to the centre of the island till it forms a plain of the general level of 2000 feet above the sea. From this plain the icy mountains of the country rise and extend in a north-easterly direction. Along this chain occur Hecla and the other volcanoes of the island; and in the same general direction, near the plain, are found hot-springs, boiling up from ridges and chasms, hissing and roaring at intervals like the sound of thunder. In the more porous strata there are smoking mud-pools, in which huge bubbles rise, that burst and throw their spray to a height of fifteen or twenty feet.

Glaciers descend to the base of the mountains, and through vast arches and chasms formed by the torrents melted from the ice by internal heat, water pours over the plain, and produces extensive morasses. A portion of this water, as it descends from the mountains, is conveyed through chasms to the hot rocks below, and thus gives rise to the boiling springs.

The geysers consist, externally, of nearly circular basins, each with an aperture in the centre, through which the hot water issues. The flow of water is intermittent, and it frequently sinks within the aperture, leaving the basin empty. An eruption is preceded by explosions of steam; water flows from the orifice, and then jets are thrown up, which occasionally reach the height of one hundred feet, but generally they do not exceed twenty or thirty feet. The eruptions seldom continue longer than a minute.

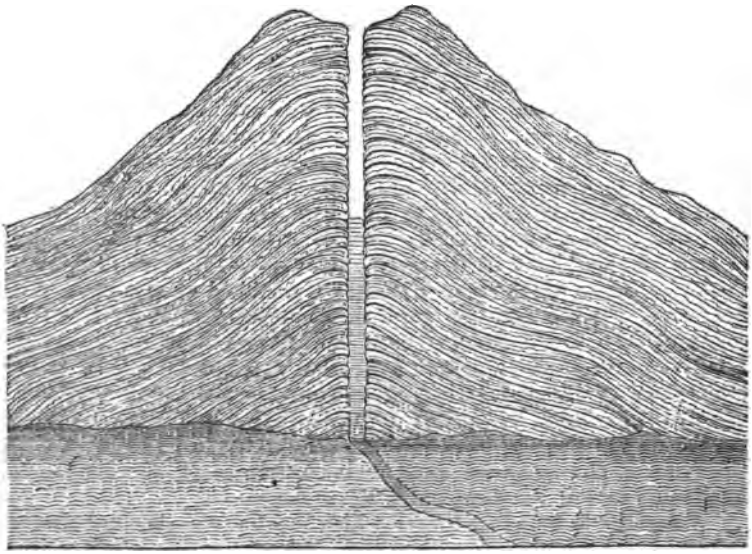
The water contains a quantity of ammonia and nitrogen, the presence of which is considered, by M. Bunsen, to prove that it is derived from the atmosphere, and not from internal sources. By chemical analysis of the water and of the rocks over which it passes, he ascertained that rain

in England were thrown down," the utmost damage that is stated to have been done is the throwing down of chimneys and the temporary stopping of water-courses. From the want of more important events, we find it noticed that during an earthquake in 1683 an ignis-fatuus was seen, and a tin vessel upset; in 1704 "doors and furniture were set it motion;" and in 1731 "doors and windows were violently shaken." In 1750, five years before the great earthquake at Lisbon, England was visited with no less than eight earthquakes. During six of these, no event occurred worthy to be noted; but of the two others it is recorded, that during one "some pigeons were frightened;" and the other was remarkable because "some dogs howled dismally, fishes threw themselves out of the water, and a horse that was brought to the watering-place refused to drink"! Let us hope that the earthquake history of England may never contain more important occurrences.

water passed over similarly heated rocks would absorb the same mineral ingredients that are found in the waters of the hot springs. Of these contents, silica and common salt (chloride of sodium) are the principal, the silica being in the proportion of 0·5079, and the chloride of sodium 0·2521.

The orifice of the great geyser was sounded to the depth of seventy feet. This tube is ten feet in diameter, and at the top it spreads out into a basin about sixty feet across. The interior of the basin and of the tube is coated with silica, which has evidently been encrusted there from the water. But the geyser water is beautifully clear, and does not deposit silica when confined; therefore it is inferred that the silica which lines, and in fact constitutes the basin, must have been deposited by evaporation during exposure to the air. From this circumstance, connected with the general structure, it is concludéd that the geysers construct their own tubes. According to this view, the great geyser was originally merely a hot spring, from which the water welled over the ground. As the water trickled over the edge it evaporated and deposited a thin crust of silica, and as the crust deposited layer upon layer, it raised a mound round the spring, and thus constructed the tube, through which the water had to rise higher at each deposition before it reached the surface. The accompanying diagram is a supposed section of the geyser, representing the formation of the tube and its surrounding mound by the successive deposition of layers of silica on the outer surface.

fig. 57.



The tube being thus formed to a certain height, the phenomena of eruption would commence, when the water became heated, by the mere effect of its own pressure, as thus explained by M. Bunsen. On lowering a thermometer down the tube, to different depths, just before an eruption, he ascertained that the temperature was nowhere so high as the boiling point would be under corresponding pressures. At the depth of forty feet from the top, the thermometer was at 122° centigrade, which is equal to 298° of Fahrenheit's thermometer; but the pressure of a column of water at that depth would raise the boiling point from 212°, at which water boils under the pressure of the atmosphere, to 302°; consequently the water was four degrees of Fahrenheit below the boiling temperature at that depth. Now it is evident that though the water would not boil under that pressure, yet if it were by any means raised in the tube, the diminution of the pressure by its elevation would produce a copious generation of steam, which would propel the fluid above it out of the tube.

The force of the steam when liberated at the surface may be conceived when it is stated, that at a temperature of 298°, the elastic force is equal to nearly twenty pounds on the square inch, and that there would be exerted on the area of the column of water an expansive power equal to 60,000 lbs. By raising the water in the tube, the whole of that pressure is brought to bear in forcing it out.

Before this explanation of the formation of geysers and their phenomena were given by M. Bunsen, it was generally supposed that the hot water collected in subterranean caverns, and that the steam pressing against the roofs of the caverns forced the water up the tube; that perpendicular aperture being regarded as an ordinary fissure in the rocks. M. Bunsen's theory, however, is so satisfactory, that it leaves little to be desired, and the suppositious caverns may be entirely dispensed with.

Respecting the primary causes of volcanoes, there are two opposing theories. One of these supposes the interior of the earth to have a temperature so high, that the materials of which it is composed are maintained in a state of fusion. It may be stated, in confirmation of this opinion, that within the range of observation, the temperature of the crust of the earth increases as we descend towards the centre, at the rate of one degree of Fahrenheit's thermometer for every sixty or seventy feet. It is calculated that if the heat goes on increasing at the same ratio to a depth of fifty miles, the temperature would be about twice as great as is necessary to fuse iron, and be sufficient to melt all the rocks which are found on the surface. Assuming this rate of increase of heat, the solid crust of the globe cannot exceed forty or fifty miles in thickness, below which every substance must be in an incandescent and fluid state. If we take for granted, therefore, that there is within a comparatively short distance from the surface—not so far as from London to Brighton—a molten fluid mass, it is not difficult to conceive that causes of disturbance may arise—such as the influx of water or of other substances expansible by heat—that would force the melted matter to the surface; especially when it is borne in mind, that the thickness of the supposed crust of the earth would be only the four-hundredth part of the diameter of the globe.

According to the other theory, which is called the chemical theory of volcanoes, the eruptions may be caused without the agency of permanent internal heat. It supposes that the metallic bases of the earths and alkalies—potassium, calcium, &c.—may be present under the surface of the earth in immense masses, and that on the influx of water they immediately combine with the oxygen it contains, producing the phenomena of combustion, and liberate the hydrogen; by which actions the eruptions of melted matter, and the explosive forces that produce them, are generated. This theory, which was originally propounded by Sir Humphry Davy, who afterwards abandoned it, has recently been adopted by Dr. Daubeny and other geologists; but the prevalent opinion is, that the proximate cause of volcanoes is to be found in internal heat.

If, therefore, we admit that there is a molten mass within a short distance from the surface, the ingenious explanation given by M. Bunsen of the eruption of the geysers of Iceland will afford also an explanation of the immediate causes why the molten matter is ejected during the eruption of volcanoes.

Under the pressure of a mass of molten lava several miles in depth, water might be confined below the boiling point though far hotter than melted iron. Even with the pressure that it is known must be exerted at the bottom of a column of lava of the height of Vesuvius, it may be estimated that water might be heated to a bright red without boiling. At the least elevation, however, of the molten mass up the chasm in the mountain, the expansive force of the steam would be developed; and thus, by its mere elevation nearer the surface, a force would be generated sufficient to eject the column of lava above it. The invariable presence of volumes of steam during volcanic eruptions indicates the presence of water among the fiery mass; and the theory of Bunsen, when applied to volcanoes, shows clearly how it may operate.

When, therefore, we perceive that by the mere elevation of the liquid lava for a few feet in the chasm of a volcano, such a vast amount of expansive force may be generated, instead of being surprised at the eruptions of existing volcanoes and at the destructive effects of earthquakes, we may rather wonder that the forces thus readily brought into action are not more frequently exerted, and do not become more destructive than they are.*

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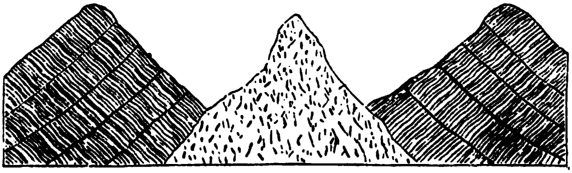
* The structure of volcanic mountains, though a question of secondary importance, has given rise to more sharp controversy than the causes of volcanic action. It is contended by some geologists, that the craters of volcanoes are invariably formed by the eruption of lava and scoriæ, which fall down on each side of the ejecting aperture; whilst it is asserted by others, that craters are most frequently produced by the upheaving of horizontal strata, and that the scoriæ and lava are subsequent deposits on that elevated cone. The terms "craters of elevation" and "craters of eruption" have been applied to signify the two modes of formation. It appears, from the structure of several cones, that the strata must have been raised with them, though it is probable that in most cases, especially those where the cavity is nearly equal in depth to the external cone, the craters have been constructed by the materials erupted. There are some remarkable instances of mountains of granite or trachyte being elevated within the craters of extinct volcanoes, which strengthen the opinion that the cones of the craters were also upheaved by internal force. In the Auvergne, the Puy de Chopine, consisting of granite, rises to a height of 900 feet within the crater of an extinct volcano. The accompanying diagram is the section of a volcanic crater, in the centre of which there is a large mass of trachyte.

fig. 58.



CHAPTER XVI.

THE INHABITANTS OF FORMER WORLDS.

Forms of animal life preserved in the transition rocks.—Tabular view of the origin and extinction of animals.—Simplest forms of animal life.—First traces of dry land in the coal formation.—Luxuriant tropical vegetation of that period.—Gigantic marine lizards: the ichthyosaurus and plesiosaurus.—The iguanodon, and other land lizards.—Flying lizards.—First appearance of land mammalia.—Vegetation of the secondary period.—Extinct herbivorous and carnivorous animals of the tertiary periods: the dinotherium, megatherium, mastodon, tiger, cat, &c.—Bone caverns.—Discovery in them of human bones with those of extinct animals.—Discovery of a recent mammoth in Siberia.—The dodo and dinornus.—Fossil infusoria.—Creation and extinction of species.—Geological evidence opposed to the progressive development of animals.

THE investigations of geologists disclose no fact more interesting to mankind than that there are embedded in solid rocks fossil remains of creatures that lived in a former condition of the world, countless ages before man was created. These relics reveal to us that during the many revolutions this planet has undergone, different tribes of beings have flourished on the face of the earth and have become extinct, and that their places have been successively supplied by other forms of animal life, generally of more complicated organizations than those which preceded them, and that they have also disappeared. Thus, after many changes, during which the successions of animal and vegetable life more and more nearly approached those of existing genera and species, we arrive at a period when the condition of animated creation exactly corresponds, in numerous instances, with that of the present.

In describing the successive formations of rocks, we have from time to time noticed the fossil remains peculiar to each, and which serve to distinguish one geological period from another. We now propose to take a continuous, though necessarily very limited and imperfect, view of the animal and vegetable creations of former worlds, pointing out the forms and organizations of the most remarkable, and tracing their courses of existence on the earth.

The shells of coralline zoophytes are among the first of the fossils that are met with in the lowest rocks of the transition series. This order of creation, which, so far as geological knowledge extends, was one of the first that appeared on the earth, has continued through all changes and convulsions down to the present period; though the existing species differ in some respects from those that formed coral rocks in the seas of former worlds. Commencing existence with the zoophytes, and accompanying them through all changes in the condition of the earth, are the echinodermata (including star fishes), the mollusca, fishes, worms, and a few other articulated animals, though none of those now living are considered to be identical in species with those of the earliest creations. At different periods, also, of the earth's progress, the number of species of these orders of creation that have been continued from the first dawn of life have varied greatly at different periods. In some the number of species at first created were few; they increased in subsequent changes of the earth, and were afterwards reduced. Others commenced with numerous species, which gradually diminished till they dwindled to very few. Others, again, commenced existence at a more recent period, and became extinct before arriving at the present condition of the globe.

The accompanying tabular view of the origin, progress, continuance, and extinction of the principal orders of living beings has been selected from a very comprehensive and scientifically arranged diagram, constructed by Dr. Carpenter for his Paleontological Lectures, and will serve better than any verbal description to show the geological periods at which different orders of animals were created, and the comparative numbers of species during their continuance on the earth. The table is divided into four columns to mark the transition, secondary, tertiary, and recent, or present, periods. The horizontal black bands indicate when the respective orders of animals first appeared; and the varied thickness of the bands shows the comparative number of the species in each successive period. Take, for example, the sea urchins; they commenced in great numbers in the secondary period; the number of species diminished in the tertiary, and increased in the present period. The nautilus commenced with a few species in the transition period, rapidly increased, and continues, with a diminishing number of species, but not exactly the same, down to the present day. The marsupialia (opossum) is represented as having commenced in the lower secondary period, become extinct in the upper, and renewed in the tertiary. This apparent break in the continuance is, however, supposed to be owing to the defective state of our knowledge, from not having yet obtained specimens, rather than to a real extinction and renewal; for it may be stated as a geological theorem, that "there has been ever a coming in of new organic forms, and an extinction of those that pre-existed on the earth, some species having endured a longer, and others a shorter time, while none have ever been renewed after once dying out."*

In the annexed table the usual arrangement into orders and classes has been disregarded, the object being to present within a limited compass a view of the origin, progress of succession, and the periods of extinction of those animals either best known, or which are marked by the strongest peculiarities in the courses of their existence on the earth.

The most remarkable and characteristic fossil of the transition period is the trilobite, a description and figures of which have been previously given.† The characters and habits of the molluscous animals that inhabited the fossil shells found in rocks of the same period present no peculiarities sufficient to arrest attention in this cursory survey of the organized systems of former worlds, and the few mutilated remains of fishes that occur in the lower transition series are chiefly remarkable for their enamelled scales; which, at the same time that they served as an excellent protection to the animals, were also the means of preserving their forms from the destroying agencies which have obliterated the traces of bones, and the more delicate parts of their organization.

The fossil remains of the lower transition rocks afford no evidence of dry land. During the long period in which those rocks were deposited,

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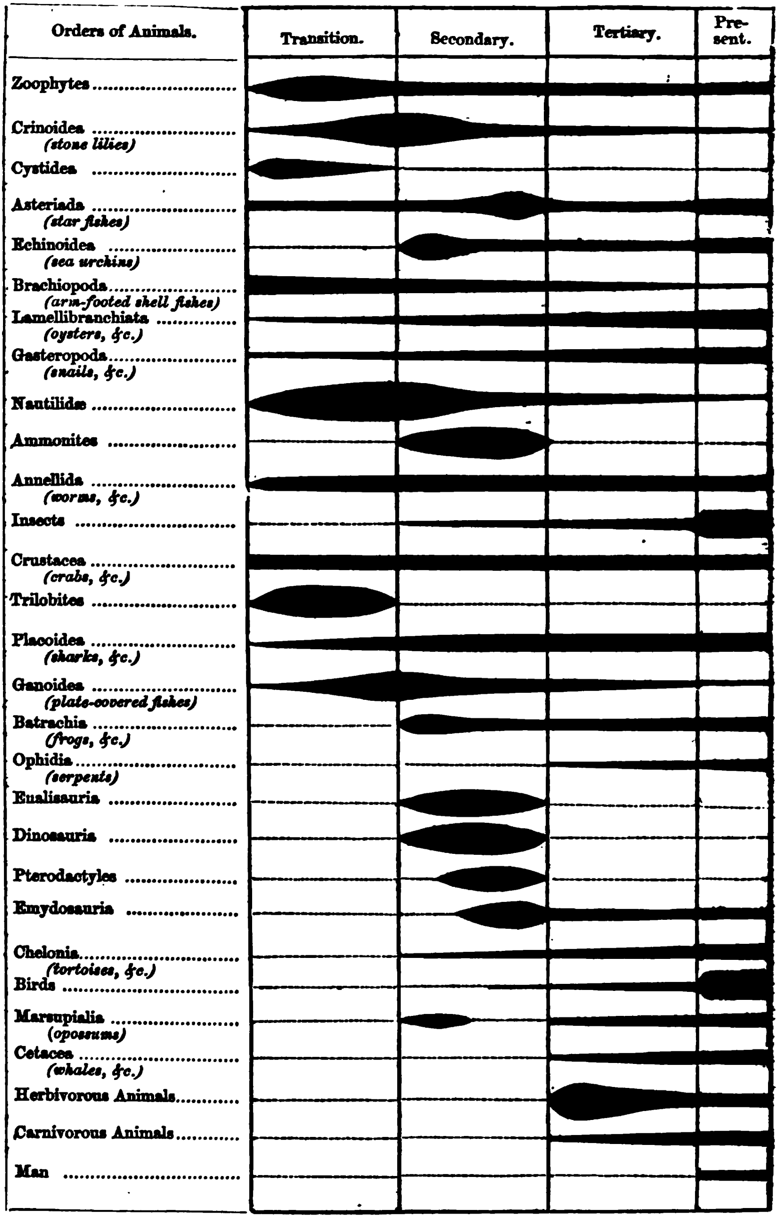
* Sir C. Lyell's Manual of Geology.

† Page 25.

THE COMMENCEMENTS AND SUCCESSIONS OF ANIMAL LIFE.



the surface of the earth appears to have been covered with water, through which the primary rocks protruded, and presented their elevated peaks to the action of water and tempests, which wasted their surfaces and mingled the fragments in the strata that are deposited upon them.

Before the carboniferous strata wer edeposited, the condition of many parts of the world underwent important changes. Large tracts of dry land were raised above the level of the sea, and in a condition eminently favourable to the growth of plants. The luxuriant vegetation of the period of the coal formation is unequalled by any at the present day; and this part of the world which now enjoys a temperate climate, was then clothed with the prolific vegetation of the torrid zone.

The principal vegetables of the coal formation present types of existing species. The common "horsetail" (equisetæ) of our swamps and ditches, ferns and pines, different in species and gigantic in size, constitute the greater portions of the plants that abound in the coal formation; whilst other trees, dispersed among the sandstones and shales that accompany the coal, are unknown at the present time, and were confined to the coal formation. Among these was a large tree called sigillaria, trunks of which have been found three feet in diameter, that are supposed to have attained a height of fifty or sixty feet. M. Ad. Brogniart, in his "History of Fossil Vegetables," considers the sigillaria to have been allied to the arborescent ferns, with smaller sized and differently arranged leaves from those of existing plants; but not a single leaf has been found attached to the trunks of these trees by which their character can be more conclusively ascertained. One of the remarkable peculiarities of the trees of the coal formation is, that nearly two-thirds of them belong to that class of plants which, like palms and canes, increase from within and enlarge their bulk by addition from the centre outwards.

The distinguishing characteristic of the animal creation during the secondary period was the abundance of marine lizards, many of which were of prodigious size. They are found most abundantly in the lias, but they became extinct before the chalk formation. The ichthyosaurus, or fish lizard, was the ruling monster of the waters. It combined the snout of a porpoise, the head of a lizard, the vertebræ of a fish, the paddles of a whale, and terminated in a long and powerful tail. The most extraordinary feature of the head was the eye, which in some of the specimens found must have been twelve inches long and nine broad. These enormous organs of vision were protected by scales which served at the same time to alter the shape of the eye, so as to render it microscopic or telescopic at the will of the animal. The jaws, which were armed with one hundred and eighty conical teeth, were in the larger species six feet long, and enabled the creature to make a terrible gape when seizing its prey. A figure representing the skeleton of the ichthyosaurus, as found in the lias strata, is given at page 48. The larger specimens were nearly thirty feet long.

The plesiosaurus must have been a still more remarkable though less formidable animal than the former. To the head of the lizard, it united the teeth of a crocodile, a neck of enormous length resembling the body of a serpent, a body and tail having the proportions of an ordinary quadruped, the ribs of a cameleon, and the paddles of a whale. These creatures appear to have lived in shallow seas and estuaries. The head was much less and proportionately shorter than that of the ichthyosaurus; the number of the vertebræ of the neck exceeded those in the neck of the swan, the tail was short, and must have acted principally as a rudder to steer the animal when swimming, or to raise or sink it in the water. The total number of vertebræ in the body was ninety.*

Existing on land at the same time that the plesiosaurus and ichthyosaurus inhabited the water, were the not less extraordinary creatures the iguanodon, the hylæosaurus or forest lizard, the megalosaurus, and the pterodactyle. The iguanodon was a monstrous lizard sixty or seventy feet long, that fed on the tropical vegetation which then grew in the swamps and on dry land. Its form resembled that of the iguana of the West Indies, which attains the length of five feet, with the addition of a horn situated like that of the rhinoceros and of about equal size.

The hylæosaurus differed in structure from every known species of living or fossil lizard, or crocodile; and though of less size than the iguanodon, its appearance must have been even more formidable. It had a row of scaly fringes on its back, seventeen inches long, which it had the power of erecting, and when thus advancing to attack its enemy or to seize its prey, it must have presented a most terrific front.

The megalosaurus approached in size the iguanodon, but it appears from the form of the jaws and teeth that it was carnivorous, and it fed, most probably, on the smaller reptiles that lived in the swamps and forests among which this creature ranged. It combined the structure of the crocodile and monitor, and must have been from forty to fifty feet in length.

The pterodactyle, though very different in appearance and comparatively diminutive in size, was scarcely less monstrous than its contemporary prodigies. With the head and general organization of a lizard, it possessed a neck resembling that of a bird; it had the wings of a bat, and a tail like that of quadrupeds. Enormous eyes enabled it to see in the dusk of twilight; and its jaws, furnished with sixty pointed teeth, adapted it to dart upon and seize fishes when hovering over the water; or to catch in its capacious mouth such insects as are found imbedded with it in the same rocks. The skeleton of the pterodactyle has been found nearly entire, of which a representation is given in figure 51. The bones agree in most respects with those of the lizard, but the joints of the fourth finger are curiously lengthened to serve for the attachment of the membrane that formed the wing. From this formation the creature derives its name.

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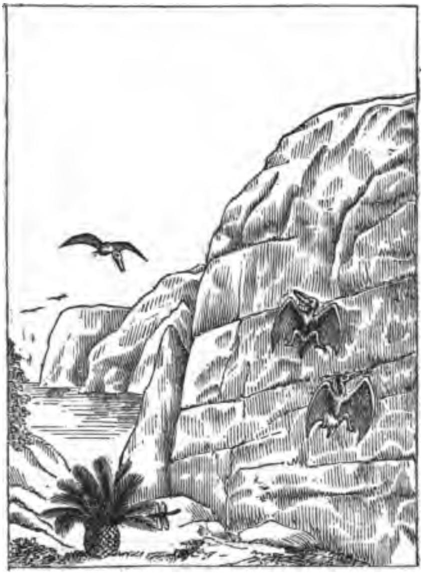
* A figure, copied from a restoration of the skeleton, by Mr. Conybeare, has been given at page 48. That gentleman has drawn the following inferences respecting the habits of the plesiosaurus:—"That it was aquatic is evident from the form of its paddles; that it was marine is almost equally so, from the remains with which it is universally associated; that it may occasionally have visited the shore, the resemblance of its extremities to those of a turtle may lead us to conjecture; its motion, however, must have been very awkward on land. Its long neck must have impeded its progress through the water, presenting a striking contrast to the organization which so admirably fits the ichthyosaurus to cut through the waves. May it not, therefore, be concluded (since in addition to these circumstances its respiration must have required frequent access of air) that it swam upon or near the surface; arching back its long neck like a swan, and occasionally darting it down at the fish which happened to float within its reach? It may, perhaps, have lurked in shoal water along the coast, concealed among the sea-weed, and raising its nostrils to the surface from a considerable depth, may have found a secure retreat from the assaults of dangerous enemies."

fig. 60.



The accompanying representation of the pterodactyle, restored and active in the scene where it is conjectured to have lived, is taken from an engraving in Dr. Buckland's "Bridgewater Treatise." Some specimens of this creature found in chalk must have had a spread of wing exceeding sixteen feet.

This period of the history of former worlds is remarkable also for the first appearance of terrestrial mammalia on the earth, though the sphere of their habitation seems to have been extremely limited. The fossil bones of an animal resembling an opossum have been found in the oolite formation at Stonesfield, near Oxford, and in no other secondary rock. The discovery of the remains of the first land animal that suckled its young in such a situation is the more remarkable, as the only living creatures allied to it are to be found in the remote continents of America and Australia. The name marsupialia, given to this order of animals, is derived from a large external pouch in which the young are placed until sufficiently matured to come forth.

The vegetation of this period still retained the tropical character that marks the plants found in the coal formation. The most abundant were those of the class called cycadæ, which now grow naturally only in tropical regions. A representation of this characteristic plant of the secondary period is shown on a small scale in the foreground of figure 60. Next in abundance were pines, and these with tree ferns, horsetails, and club moss of gigantic sizes, constituted almost the sole vegetation of the secondary period, during which the earth was still, for the most part, covered with water. Roaming among this tropical vegetation in swamps and forests on the sea shore, or swimming about in the deep waters, at the same time with the monstrous animals we have briefly described, were crocodiles, serpents, turtles, tortoises, sharks, and innumerable fishes, more or less resembling in general characters those of the present day, but none of them exactly alike to any that are now living.

At the end of the secondary period as marked a change occurred on the face of the earth and in the character of its inhabitants as that which distinguished its commencement. The dry ground was greatly extended, and the valleys formed by the elevation of the land were traversed by mighty rivers, or they became the beds of extensive freshwater lakes. At this time, land quadrupeds, which had been previously very scantily represented by a few analogous to opossums, became more numerous; herbivorous and carnivorous animals existed in abundance; and crocodiles and tortoises lived on the banks of the fresh-water lakes. It is now for the first time there is distinct evidence that birds took their flight through the air of that ancient world, though some footprints preserved in the new red sandstone denote that wading birds had traversed the sea shores at much earlier periods.

The discovery of stores of organic remains in the gypsum beds of the older tertiary formation near Paris, first directed Cuvier's attention to the examination of fossil bones, and led to the knowledge of the preexistence of animals that have now ceased to live.

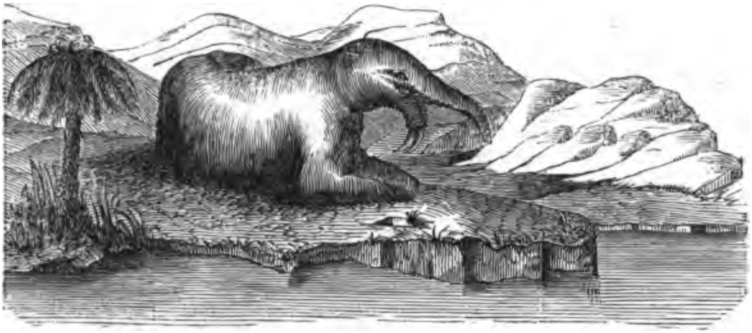
From the charnel house of separated fossil bones, Cuvier was enabled to determine the previous existence of seven orders of extinct animals, containing many species that had lived either on land or in fresh water at that period. Of the land animals, the most remarkable was the palæotherium, an animal intermediate between the rhinoceros, the horse and the tapir, some specimens of which must have been as large as a rhinoceros, whilst others were of the size of a hog. A representation of one of these animals, as restored by Cuvier, has been given in page 64.

Wolves, foxes, racoons, genettes, dormice, squirrels, nine or ten species of birds, including owls, buzzards, woodcocks, and pelicans, were among the animals that lived during the lower tertiary period; but the large reptiles that abounded during the previous stage of the world's history had disappeared. The temperature of this part of the globe had been sensibly diminished after the elevation of the land, but palms still grew and flourished.

The middle tertiary formation contains the remains of animals which approach near to those of the present day, and mingled with them are some of the animals of the preceding period. Those, however, which are allied to animals now living must have been very different in many respects, especially in size. There are the bones of cats which must have been as large as tigers, and of an animal allied to the dog of the size of a lion. Tapirs, larger than any living species, roamed on the banks of the lakes and rivers, accompanied by the rhinoceros, and with animals resembling horses, bears, hogs, and the mastodons of the succeeding geological age. The most remarkable, however, of all the herbivorous mammalia of that period was the dinotherium, a gigantic aquatic animal much longer than any terrestrial animal yet discovered, measuring in some instances eighteen feet. The peculiar feature of its anatomy is the lower jaw, the fossil bones of which are represented in fig. 47. The accompanying wood-cut shows the supposed form of the animal when living. An enormous tusk in the forepart of the lower jaw on each side bent downwards, and when the mouth of the dinotherium was shut, it must have resembled on a large scale the mouth of a walrus, though the descending tusks of the latter are placed in the upper jaw.

In the upper tertiary formation, including the diluvial and alluvial deposits, we are brought still more closely to the state of animal existence which prevails at the present time. Bones of the elephant, the rhinoceros, the hippopotamus, the tiger, and the leopard indicate distinctly that the climate in this latitude, even at that comparatively recent period, was much warmer than at present. At that time, it is conjectured, England was connected with the Continent, and that the inhabitants of tropical climes roamed here as on to a remote promontory joined by an isthmus to France and to those other parts of Europe where the remains of similar animals are found.

fig. 61.



Though we have classed the upper tertiary formation as belonging to the same period, there is little doubt that its deposition was not completed until after a long succession of ages, during which the condition of the land and the character of its inhabitants underwent many changes. This is apparent by the extinction of some of the animals we have just mentioned previous to the disappearance of others which afterwards became extinct. Thus, the mastodon, which is the type of the elephant, though of a different species, died out long before the mammoth and the elk disappeared from the face of the earth. Even the valley deposits, from the surfaces of the hills as we now see them, contain the remains of animals not only long since alien to this island, but which have become altogether extinct, and are represented in other climes by different species of the same genera.

The principal distinction between the mastodon and the elephant was in the shape and structure of the teeth, and the mastodon possessed short tusks in its lower, in addition to those in its upper, jaw. "It has been conjectured that the mastodons were more aquatic, or swamp-hunting quadrupeds than the elephants; their limbs were, however, proportionally shorter, although constructed on the same type, each foot being terminated by five short and stout toes, which were evidently, from the form of the last phalanx, confined in one common thick hoof."*

The skeleton of a mastodon almost entire, found in the valley of the Missouri, was, ten years since, exhibited in London as the "Missouri Leviathan," a greater number of bones and ribs than belonged to the living animal having been added to increase its attractions as a monster of former worlds. It was purchased for the British Museum, where it is now to be seen, after having had all the extraneous bones removed, so as to reduce the skeleton to its proper proportions, as shown in the annexed woodcut.

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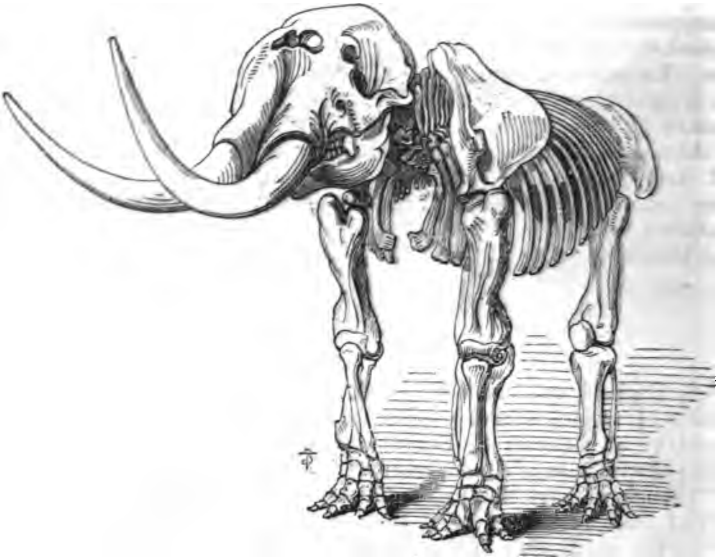
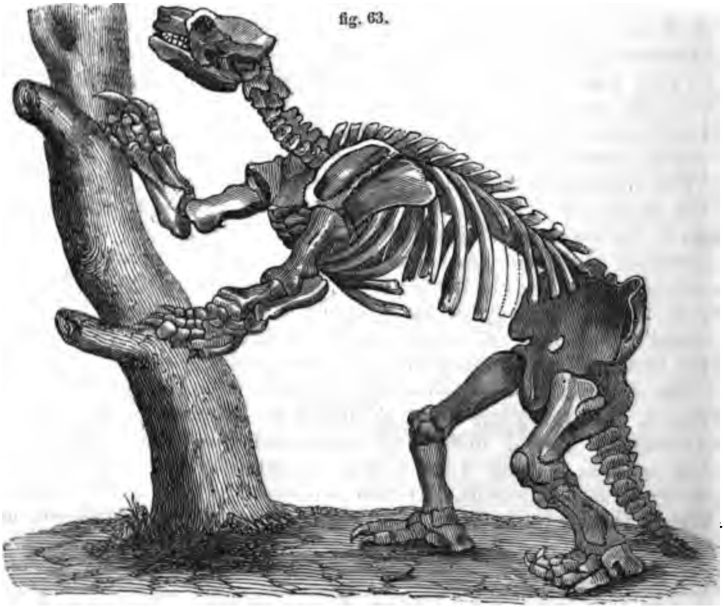
* Professor Owen's "History of British Fossil Mammals."

fig. 62.



Another fossil skeleton, of monstrous size, from America, is placed near the mastodon in the British Museum, and is supposed to have

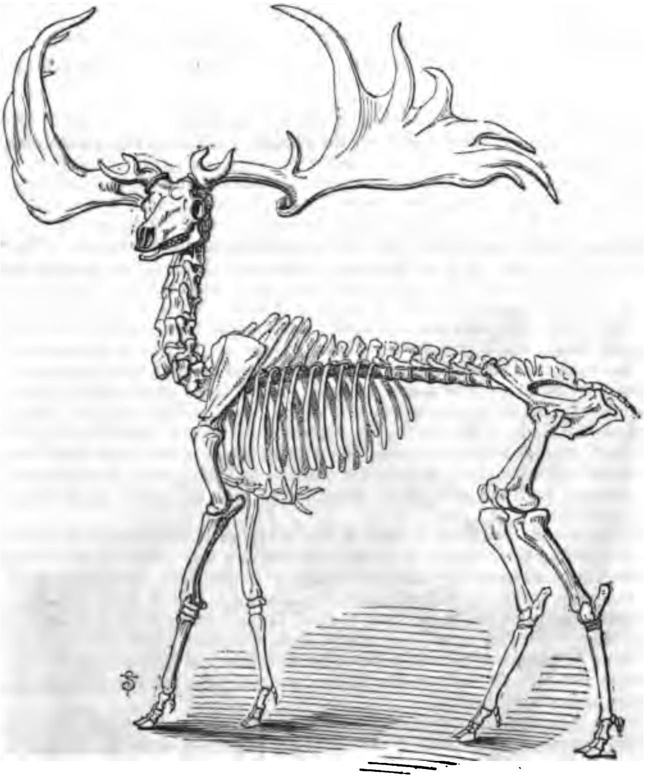
fig. 63.



lived at the same period. The megatherium was a gigantic sloth larger than a rhinoceros, with legs and tail exceeding in strength those of any other animal. With the head and shoulders of a sloth, it combined in its legs and feet the characters of the ant-eater and the armadillo, and it is supposed to have still further resembled the armadillo by being encased in bony armour, which in parts was an inch and a half in thickness. Its haunches were more than five feet wide, and its body twelve feet long and eight feet high. Its feet were a yard in length, and terminated in enormous claws.

Abundant evidence exists in the bones and teeth found in the lake and river deposits of the most recent tertiary period, and in the still more recent alluvial deposits, that England and Ireland were formerly inhabited by tribes of animals now extinct, which lived and died near the places where their bones are discovered. The Irish elk (fig. 64) is one of these relics, some magnificent specimens of which are contained in the Dublin Museum. The insect feeders of the same period were represented by bats, moles, and shrews; and the rodent order by two

fig. 64.



kinds of beaver, by hares and rabbits, water voles and field voles, rats and mice.*

The remains of these animals generally occur in the most recent of the diluvial and alluvial deposits, and among the strata which contain a very large proportion of fossil shells similar in species to those now found in neighbouring seas. The most abundant collections of those fossil bones have, however, been found in limestone caverns of geologically recent formation, into which the animals had retired to die, or where their limbs had been dragged by carnivorous animals to be gnawed. Many of the remains found in these caverns bear fresh-looking marks of their having been gnawed by the hyænas, whose bones are mingled with them. In Dr. Buckland's "Reliquiæ Diluvianæ," ample descriptions and drawings are given of the caves where they are found, and of the appearance and condition of the bones. Kirkdale cave, in Yorkshire, and Banwell cave, in Somersetshire, have attracted especial notice from having been discovered within the last thirty-five years, and carefully examined before the fossils had been much disturbed. In those caves were found remains of the tiger, bear, hyæna, wolf, fox, and weasel, mingled with those of the elephant, rhinoceros, hippopotamus, horse, hare, rabbit, rat, water-rat, mouse, ox, and deer; and the bones of the raven, pigeon, lark, snipe, and duck, were also among them. Dr. Buckland inferred, from the great number of the bones of the hyæna, and from the mingling together of the remains of herbivorous with carnivorous animals, that the caves formed the dens of hyænas, and that the bones are those of animals which they had carried in to devour. The small size of the openings to the caverns would, indeed, have precluded the entrance of the larger animals until their bodies had been dismembered.

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* Professor Owen, in the introduction to his valuable work on the "History of British Fossil Mammals," thus describes the condition of animal life immediately before the creation of man:—

"At the period indicated by those superficial stratified and unstratified deposits, the mastodon had probably disappeared from England; but gigantic elephants, of nearly twice the bulk of the largest individuals that now exist in Ceylon and Africa, roamed here in herds, if one may judge from the abundance of their remains. Two-horned rhinoceroses, of at least two species, forced their way through the ancient forests, or wallowed in the swamps. The lakes and rivers were tenanted by hippopotamuses as bulky and with as formidable tusks as those of Africa. Three kinds of wild oxen, two of which were of colossal size and strength; and one of them, maned and villous like the bonassus, found subsistence in the plains. Deer, as gigantic in proportion to existing species, were the contemporaries of the old *uri* and *bisontes*, and may have disputed with them the pasturage of that ancient land; one of these extinct deer is well known as the Irish elk, by the enormous expanse of its broad-palmed antlers; another herd proves more like those of the wapiti, but surpassed that great Canadian deer in bulk; a third extinct species more resembled the Indian hippelaphus; and with these were associated the red deer, the rein deer, the roebuck and the goat. A wild horse, a wild ass, or quagga, and the wild boar, entered also into the series of British pliocene hoofed mammalia.

"The carnivora, organised to enjoy a life of rapine at the expense of the vegetable feeders, to restrain their undue increase, and abridge the pangs of the maimed and sickly, were duly adjusted in size and ferocity to the fell task assigned to them in the organic economy of the pre-Adamite world. Besides a British tiger of larger size and with proportionally longer paws than that of Bengal, there existed a stranger feline animal (*machairodus*), of equal size, which, from the great length and sharpness of its sabre-shaped canines, was probably the most ferocious and destructive of its peculiarly carnivorous family. Of the smaller felines, we recognise the remains of a leopard, a large lynx, and of a wild cat.

"Troops of hyænas, larger than the fierce crocuta of South Africa, which they most resembled, crunched the bones of the carcases relinquished by the nobler beasts of prey; and doubtless often themselves waged the war of destruction on the feebler quadrupeds. A savage bear, surpassing in size the *ursus ferox* of the Rocky Mountains, found its hiding-place, like the hyæna, in many of the existing limestone caverns of England. With the *ursus spelæus* was associated another bear, more like the common European species, but larger than the present individuals of the *ursus Arctos*. Wolves and foxes, the badger, the otter, and foumart, and the stoat, complete the category of the known pliocene carnivora of Britain."

In Germany, the bone caverns are much larger than those in this country. At Addlesberg, in Carniola, there is a cavern, or connected series of caverns, of various dimensions, which extend for three leagues in a straight line. The floors of this suite of caverns, many of which are now difficult of access, are covered with indurated clay, enclosing the bones of bears and other carnivorous animals for several miles.

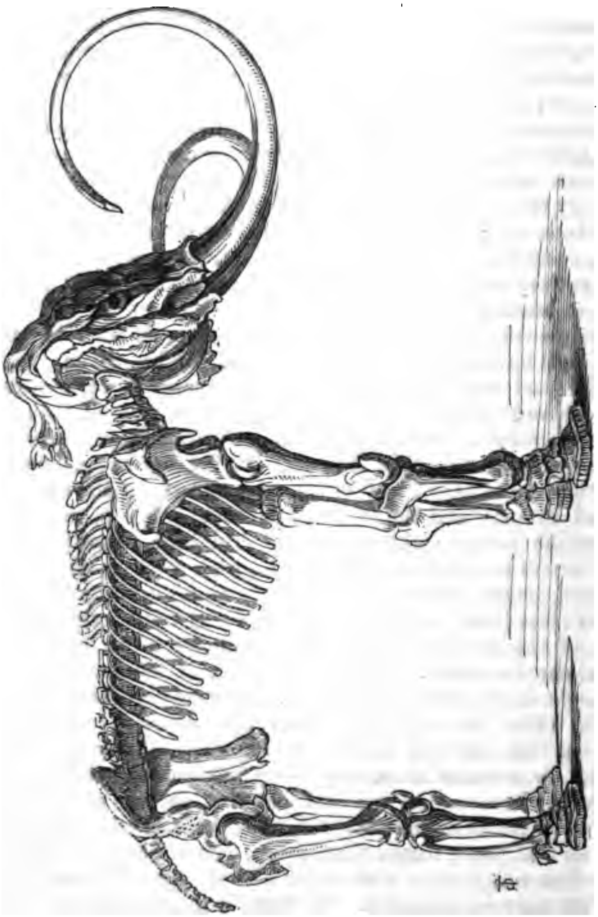
The bone caverns of France and Belgium derive additional interest from the occurrence of human bones, sometimes accompanied with pieces of rude pottery and stone hatchets, mingled with those of extinct carnivorous and herbivorous animals.

The discovery of human bones thus associated with the remains of animals that have disappeared from the earth, has given rise to much speculation and controversy, as that fact appears to contradict the previously generally admitted position that the creation of man was subsequent to the diluvial depositions. The exception may, however, be considered in this case to prove the rule. It is absurd to suppose that any race of men would have lived in the same caverns at the same time with tigers and hyænas, and the most likely supposition is, that these caves, long after the bones of extinct animals had been deposited, were made places of sepulture, or that they were resorted to as places of safety. It is conjectured, indeed, that the human bones found in some of these caverns may have been those into which the natives of Gaul retreated during the invasion of Cæsar, who ordered the entrances to be closed, and thus caused them to perish. The preservation of human bones in caves which might have been recently used by man, and the absence of such bones in other than merely superficial deposits, tend to confirm the opinion that had man existed on the earth in former conditions of the world, his remains must have been found among the deposits which contain such abundance of the fossil bones of animals of all kinds.

The bones found in caves are not usually fossilized. They are generally lighter and more fragile than recent bones, but they contain a large portion of animal matter, with which also the osseous mud that encloses them is strongly impregnated. So fresh is their condition, indeed, that in some places the bones are excavated and spread over the land for manure. This application of the animal matter of extinct animals to the support of living beings, affords a fine subject for contemplation to the speculative philosopher.

There are, however, even better preserved remains of some of the inhabitants of the former world than those of the bone caverns. The ice and the frozen ground of the Arctic regions, where the earth is constantly frozen at the depth of a few feet, have preserved some specimens of the mammoths and extinct bears in such a condition that their flesh, covered with skin and clothed with wool and hair, was not decomposed. The most remarkable discovery of this kind was that of the Siberian mammoth in 1801. When discovered, the whole animal was preserved imbedded in ice, with its flesh, skin, and hair as perfect as if recently dead. According to the discoverer, the animal, when first disclosed from the ice, was so fat that its belly hung below the joints of the knees. This mammoth was a male, with a long mane on the neck; the skin, of which about three-fourths were saved, was of a dark colour, covered with a reddish wool and coarse long black hairs. The skeleton, from the fore-part of the skull to the end of the tail, measured sixteen feet four inches; its height was twelve feet. The tusks measured, along the curve, nine feet six inches; and in a straight line from the base to the point, three feet seven inches. The skeleton is now mounted in the museum of the Petropolitan Academy. It is represented in the accompanying drawing, as given by Professor Owen in his "History of Fossil Mammals."

fig. 65.

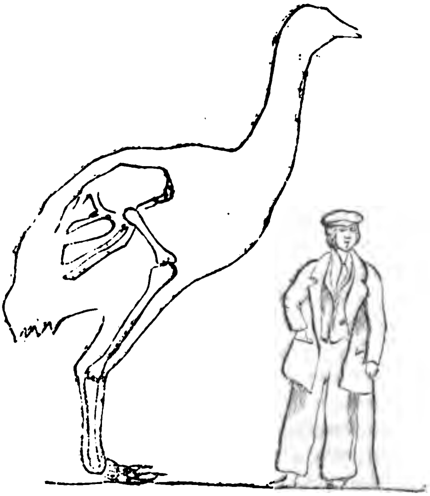


A part of the skin, and some of the hair, are in the museum of the College of Surgeons. The hair is separated from the skin, excepting in one part, where it is thick-set and crisply curled, and is interspersed with a few bristles about three inches long, of a dark reddish colour. Among the separate parcels of hair are some about four inches long, and some bristly, nearly black, and from twelve to eighteen inches in length. The skin, when first taken to the museum, smelt offensively, but it is now quite hard, and in the most compact part is half an inch thick.

Professor Owen is decidedly of opinion that the mammoth was specifically different from the elephant. The differences in the bones and in the teeth are, he states, sufficient to establish the distinction; and this is made still more apparent by the thick hairy covering of the Siberian specimen. The mammoth he conceives to have been adapted to live in cold climates, and the distribution of the fossil remains of that animal almost exclusively in temperate and frigid zones seems to indicate that it was distinct from the Asiatic and African elephants.

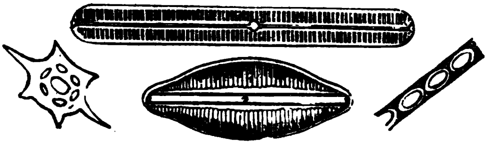
The extinction of species is not, however, confined to changes in the condition of the globe. The dodo, a bird that inhabited the Isle of France, and is supposed to have been living within the last hundred years, is now altogether extinct; though it often figures in works of natural history as still living. The only relic of the dodo with its plumage was a stuffed specimen in the Ashmolean Museum, but its rarity not being known, it was a few years ago destroyed as being in a bad state of preservation. Another bird, called by Professor Owen the dinornis, which inhabited Australia, and must have greatly surpassed the ostrich in size, is supposed to have but very recently become extinct. There is, indeed, some ground for believing that this monster bird may be still living in unexplored parts of the country. The accompanying outline represents the dinornis as restored by Professor Owen. The bones figured in the hind leg are the only portions of its skeleton which had been found when that skilful comparative anatomist built up from those slight foundations the form and size of the bird, and was enabled to describe its character and habits.

fig. 66.



In the cursory notice of the inhabitants of former worlds that our limits will admit, we have directed attention chiefly to the larger objects of creation; but then, as now, the same Infinite Power that made the monsters of the sea and land was equally exerted in the organization of the minutest animalculæ. Ehrenberg, the distinguished German naturalist, by directing his microscopic investigations to the dust of former worlds, has discovered that it once swarmed with life. Tripoli powder, for example, is composed of countless numbers of delicately organized infusoria, which have been fossilized by silica. So minutely small are those silicified skeletons, that it is calculated that 41,000,000 are contained in one cubic inch of stone. A magnified representation of some of these fossils is shown in figure 67.

fig. 67.



When we perceive that in the successive changes which the surface of the earth has undergone, certain orders and species of animals become extinct and are followed by others, the question naturally suggests itself, were these changes produced according to some general law by which all things are extinguished and created anew, or were they special occurrences, and dependent on the special exercise of creative power? It has been conjectured that species, like individuals, may have the cause of their death inherent in their original constitution; and that the limit of existence may have been ordained from the commencement of each. This opinion derives some countenance from the fact that certain species of molluscous animals have continued to exist during all changes in the condition of the world, whilst others became extinct.

Human knowledge does not at present extend far enough to throw a clear light on this interesting subject. It has been established by geological researches that there has ever been, since the first dawn of creation, progressive changes in the crust of the globe, which have fitted it more and more for the habitation of man; and the progressive complication of animal organization, from its most simple forms in zoophytes to the complicated organism of human beings, has encouraged the notion that more perfect organizations have been progressively developed from those that were less so. This notion of the progressive development of living beings from each other, though it may seem at first sight to derive support from the facts of geology, is in reality directly contradicted by them. In the first place, there is no imperfection in the organization of the lower orders of animals. In the discharge of their respective functions, and for the enjoyment of the existence to which they were destined, the organization of all was perfect; and the addition of a higher degree of locomotive power or of intelligence, would have unfitted them for the work they had to perform. The same may be said of all the intermediate orders of beings between zoophytes and man. To each one has been given an organization and intellectual capacity admirably adapted to its wants, and best calculated to administer to its enjoyment of life. It would be out of place in this introductory treatise to enter at large into the consideration of this subject, but it may be stated generally, that though varieties of species may be produced by change of circumstances and by climate, no distinctly marked species is ever known to mix and lose its distinctive characters; still less can it be conceived that such remarkable changes in the character of the inhabitants of the world as occurred from the transition to the secondary and from the secondary to the tertiary periods, could have been brought about by any mingling of breeds, or other means of progressive development, of which there is not the slightest appearance. We are bound, therefore, by geological evidence, to believe that so far from there having been a progressive development, each distinct order of beings, and each separate species, was specially created.

CHAPTER XVII.

GEOLOGICAL GEOGRAPHY.

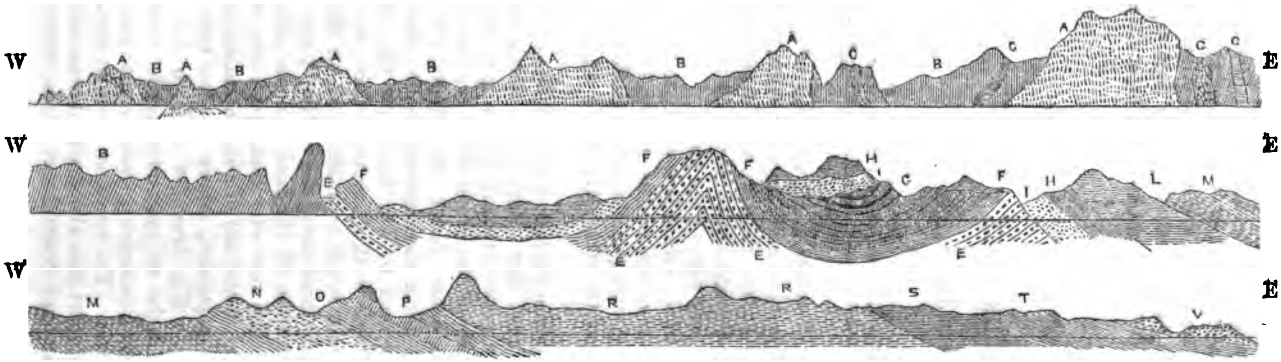
The Geology of England and Scotland.—Geological map of Great Britain.—Geology of Europe.—Illustrative map.—Similar rocks and successions of strata in Asia and Africa.—Geology of North and South America.—Australia and the gold diggings.

THE rocks and strata of England combine all varieties of geological formations, from the diluvial deposits and upper tertiaries to the secondary, transition, and primary rocks; thus, within the small compass of our island, the geologist may find specimens of nearly all the classes of rocks that are to be met with in every part of the globe.

The general dip or inclination of the strata is towards the south-east, so that each stratum in succession comes to the surface on travelling from east to west; and the accompanying section, from Suffolk to Cornwall, presents a good illustration of the successive strata and beds that compose the crust of the earth.

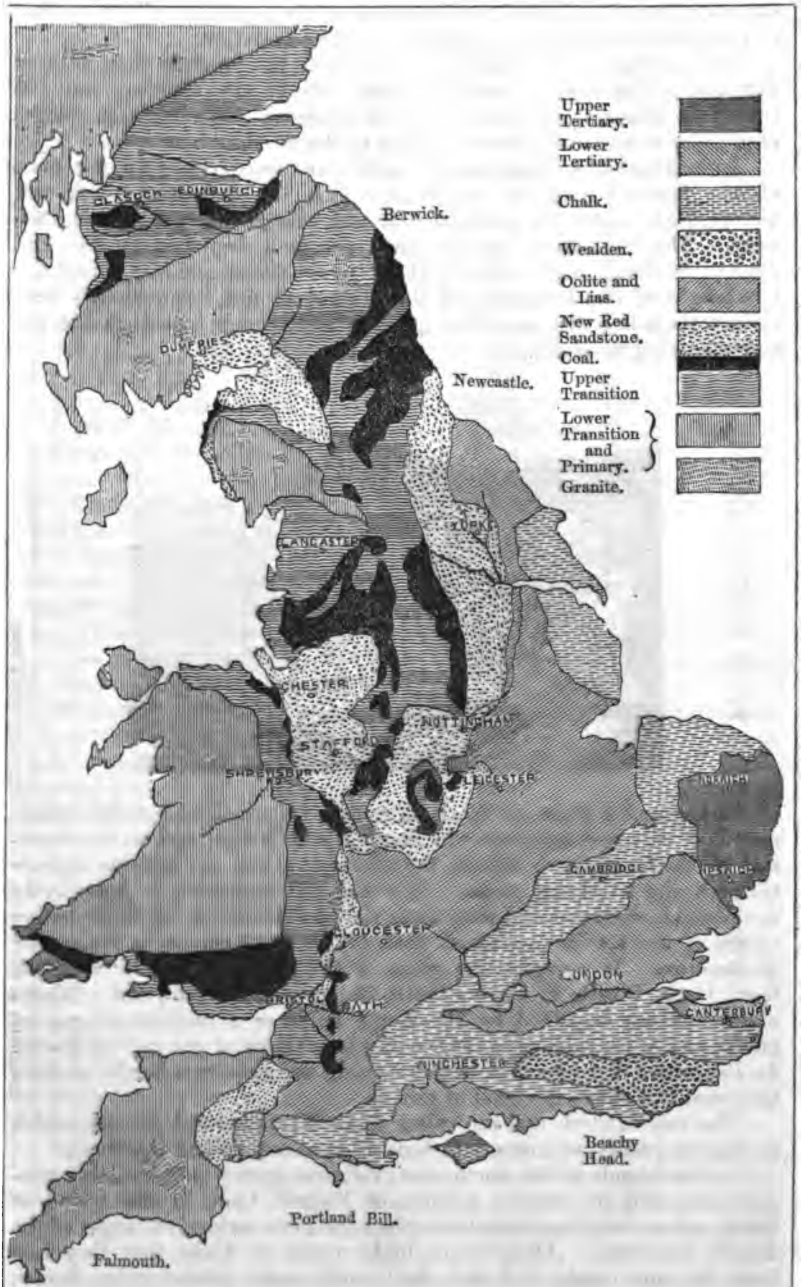
In the rocks and strata of England there is a remarkable conformity in their succession to each other, and they range from north to south with general continuity, as shown very distinctly in the geological map of Great Britain. On the west side of the island there are the primary rocks; in the central division there occur the upper transition and lower secondary strata; and along the east the oolite, chalk, and tertiary strata. It has been observed by Dr. Buckland that if three foreigners, previously unacquainted with England, were to travel separately through the country from south to north, one on the west, another through the centre, and a third along the eastern parts of the island, their reports of the condition of England and its population would be at complete variance. The one who took his route through Cornwall, Wales, and Cumberland, would tell of a mountainous country, barren of vegetation, and thinly populated, where the few inhabitants were chiefly occupied in mining. The traveller through the central portions would describe England to be an extremely fertile, undulating country, inhabited by a crowded, energetic, industrious population principally engaged in manufactures. The traveller through the eastern counties, on the contrary, would report that the chalky downs and plains of Albion present rich pasture land and fruitful corn fields, and that the pursuits of the inhabitants are almost exclusively agricultural. Such contradictory reports would be separately correct, and when examined collectively would afford a striking illustration of the influence in the

SECTION OF COUNTRY FROM LAND'S END TO SUFFOLK.



The upper portion of the section commences on the left with the Lizard's Point, and continues to the eastward slope of Dartmoor. The middle portion connects on the left with the one above, and comprises the range of country across the Quantock and the Mendip Hills to the south-western part of Oxfordshire. The lowest division continues the section in a north-easterly direction, to near Harwich on the Suffolk coast. The letters A, A, A, indicate the points where the granite protrudes at elevations varying from 400 feet near Land's End, to 800 at Redruth, 1000 at North St. Austell, and 1790 at Dartmoor. Resting upon the granite are the slate rocks and schist B, B, B, intersected by metallic dikes and by veins of basalt and other igneous rocks, C, C, C. The series of slates terminates at the Quantock Hills, at a height of 1270 feet. The old red sandstone E, next appears, followed by mountain limestone, F; and resting upon the latter are the new red sandstone and lias; the coal measures being absent on the western side of the Mendip Hills. The old red sandstone and the mountain limestone have there been upheaved to the height of 1100 feet by some convulsive movement that has elevated the strata almost vertically, and formed basins on each side of the axis of elevation. On the east of the Mendip Hills the coal measures of Somersetshire, G, are well developed, and the new red sandstone, lias, and oolite rest upon them unconformably; and at Dundry Hill, H, the oolite attains the height of 700 feet. The same strata are seen farther to the east, where they, the oolites, with their intermediate beds of clays, M, M, N, O, P, occupy an extensive tract of country. Those strata are succeeded by the chalk R, R, and S; the latter, or upper chalk, containing flints. The London clay is shown at T, and the section terminates at the German Ocean with the Suffolk crag.

GEOLOGICAL MAP OF GREAT BRITAIN.

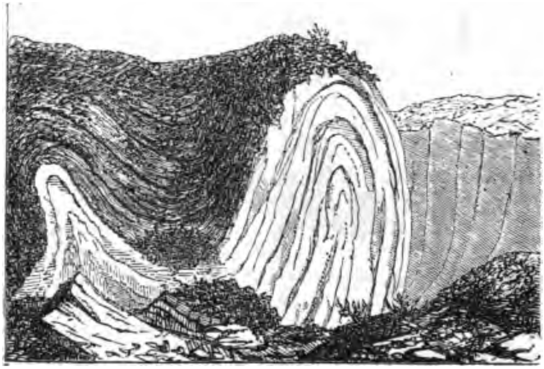


same country of geological conformation on the condition of the surface and on the character and occupations of the population.

The geology of Scotland presents much less variety than that of England. The tertiary and secondary strata are wanting, and the transition strata occupy principally an extensive plain between ranges of primary mountains to the south and to the north.

Indications of violent internal action are conspicuous among most of the igneous rocks in Scotland, which has dislocated them and distorted the strata by perpendicular upheavings and lateral compressions. The contortions of the strata are well displayed on the east coast of Scotland near St. Abb's Head, where the slate cliffs, which rise to a height of two hundred and three hundred feet, are distinctly bent sixteen times in a distance of six miles in the manner represented in the accompanying wood-cut.

fig. 70.



The primary rocks of Scotland consist principally of gneiss, which rock is of very rare occurrence in England and Wales; and on the north-east of the Grampians, and in the extreme north, the granite appears through the overlying gneiss. The old red sandstone is extensively developed in Scotland, and rests upon the gneiss without the intervention of any of the fossiliferous strata that are so conspicuous in Wales and Devonshire. It occupies the whole of the northern part of Scotland, from Cape Wrath to the southern flanks of the Grampians. Those mountains are described by Mr. Hugh Miller as a nucleus of granite, gneiss, and other primary rocks set in a framework of old red sandstone. In Ross-shire it is two thousand feet thick, and rises to a height of three thousand feet above the level of the sea.

The vale of Clyde and the valley of the Forth are rich in coal, which is of good quality, and occurs in beds of great extent and thickness.

In the islands to the north-west, volcanic agency is remarkably conspicuous; and the basaltic columns of Fingal's Cave, in the Island of Staffa, are scarcely less remarkable than the more extensive ranges of the Giant's Causeway. There seems little reason to doubt that they had both the same origin, and that the basaltic rocks extend under the sea from the Hebrides to the north of Ireland.

The physical geography of Ireland presents the remarkable peculiarity of chains of primary and transition mountains on the east and west coasts of the island, and a low level throughout the central parts. In consequence of this configuration of the country, there is a very imperfect drainage in the centre of Ireland, and vast tracts of swamps and bogs. Granite rises to the surface in the county of Dublin, where it forms a range of mountains about twelve hundred feet above the level of the sea, the rounded summits of which contrast with the serrated and peaked slate mountains of the adjoining county of Wicklow. Granite also shows itself through the slate rocks on the opposite side of the island, in Galway, and to the north, in the county of Antrim. The carboniferous limestone occupies two-thirds of the entire country.

The coal districts of Ireland lie detached, at great distances apart, and occupy but small areas. The principal part of the small supply has been already worked out.

The new red sandstone is sparingly developed. The districts in which it is found are in the counties of Tyrone and Antrim; and the most southern part where the new red sandstone is met with is in the county of Monaghan. In sinking through the red marl in search of coal, beds of valuable rock-salt have been found at Carrickfergus. The new red sandstone is covered by lias, as in England, and that again by chalk; but the chalk of Ireland, which occurs only in the north-east, is harder than the common chalk of England, and is called white limestone. Tertiary strata are distributed in several parts. On the south side of Lough Neagh, and in the counties of Tyrone and Down, and in the counties of Wicklow, Wexford, and Waterford, there are tertiary strata, but they do not occupy extensive areas.

A remarkable feature in the geology of Ireland, which distinguishes it from England, is the extensive range of basaltic rocks on the north coast of Antrim, which covers an area of 1000 square miles. Great basaltic dikes also range from east to west in the province of Connaught, which are supposed to be connected with the overlying basalt in Antrim.

In many of the central parts of the country there are peculiar deposits of gravel called "eskers," which are well defined narrow ridges of pure gravel, which can be distinctly traced for twenty or thirty miles, and bear a striking resemblance to a railway embankment. These superficial deposits are supposed to have been occasioned by the presumed "northern drift," which has swept along the low part of the country.

On looking at the geological map of Europe,* it will be observed that the same rocks and strata which occur in such regular succession, and come to the surface as we pass from the east to the west of England, occur also on most parts of the Continent, but they are there dispersed without having any principal axis of elevation.

On the north-west coast of France, the primary rocks occupy an extensive district, being, most probably, a continuation of the Cornish and Devonshire rocks. To the east of those primary beds there is also a repetition of some of the midland strata of England. In Normandy

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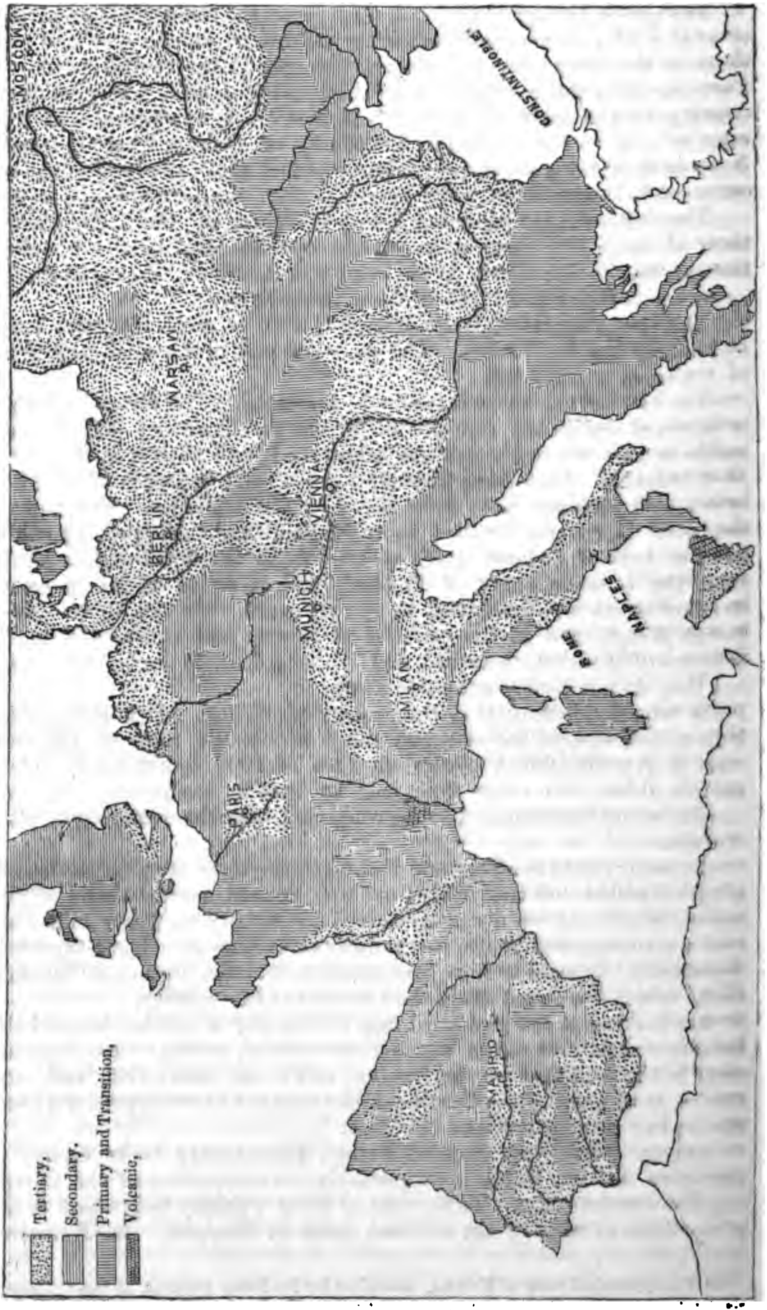
* The geological map of Europe, compiled by Professor Phillips, in the "Encyclopædia Metropolitana," has been principally adhered to in the accompanying map.

GEOLOGICAL MAP OF EUROPE.



we meet with the same oolite, at Caen, which constitutes the building stone at Bath; and farther to the east there is a range of chalk cliffs like those on the south coast of England. In the centre of France, also, from Paris to Metz, the succession of strata is similar to the section of the country from London to Cheltenham, with the escarpments of the hills reversed. The oolite and chalk sweep in a vast circle round Paris, from Normandy to Calais, Lille, Saumur to the mouth of the Seine, and they occur again in the south of France.

The depositions of tertiary strata near Paris closely correspond with those of the vale of Thames, the same strata being, it is assumed, continued under the English Channel.

As we proceed towards the south of France, the correspondence in the arrangement of strata with those of England disappears. The tertiary beds possess much more prominence in the geological features of the country, and occupy extensive districts in the south and south-west. Nor have the primary rocks a bearing towards one point of the compass, as in England, but present themselves in the north-west, in the south, and in the south-west, and rise in the Alps to greater elevations than any other mountains in Europe. Another characteristic difference between the geology of England and that of France is the occurrence in the Auvergne of an extensive range of extinct volcanoes, with accompanying volcanic products. The lower transition rocks are very scantily represented by a range of limited extent in Britanny; and the granite in the Alps, instead of being accompanied by the usual primary rocks, is strangely associated with tertiary strata that have been elevated with it to a height of ten thousand feet.

We shall not attempt to trace the various rock formations to their particular localities in the different parts of Europe. The places where they are best developed have been previously mentioned as they were separately noticed, and the accompanying map will convey an idea of the general distribution of the rocks in the geological series.

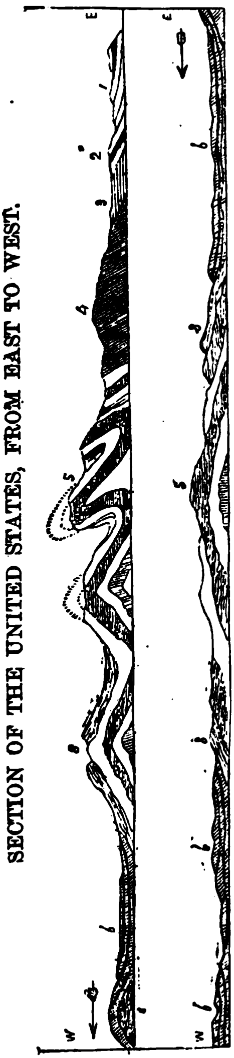
So far as the geology of Asia and Africa is known, it denotes a similar occurrence of the same classes of rocks, following in the same order of succession as those of Europe. In the mountain ranges there are found granite and the lower transition rocks, and the secondary and tertiary strata are also abundantly distributed in the lower lands. The rocks contain corresponding fossils, and they exhibit evidences of similar disturbances by elevation, subsidence, and volcanic action. In the great Himalaya chain of northern India, which is two thousand miles long and from one hundred to three hundred miles in breadth, granite occurs at a height of 25,000 feet; the lower transition rocks occupy a zone at elevations varying from fifteen to eighteen thousand feet high; and recent tertiary beds, containing fossil remains of quadrupeds and shells, are met with at a height of eighteen thousand feet. There are several extensive coal districts in India, containing many workable beds of good coal.

The mountains of Africa also exhibit successions of the same rocks; and the immense sandy deserts, covered with salt and containing shells, indicate that the central portion of that continent has been, at no distant geological period, covered by the ocean.

If we cross the Atlantic, and examine the geological structure of the vast continent of America, similar rocks, subject to the same law of arrangement, are met with as in the Old World; and volcanic action is there conspicuous on a magnificent scale. The Andes, which range north and south through the whole extent of South America, have been compared to a vast volcanic dike, from two to three miles high, and from one hundred to two hundred miles broad, in which there may be seen thirty volcanoes exhibiting signs of activity. The base of this extensive mountain chain is granite, which rises to a height of from five thousand to ten thousand feet. Incumbent upon it are gneiss, mica-slate, primary limestone, and clay slate, though they seldom occur continuously. Resting upon these rocks, as on elevated pedestals, are immense masses of old porphyry, on which again there rest other beds of porphyry of more recent deposition, rich in metals; and those rocks are frequently associated with basalt, clinkstone, and amygdaloid. The volcanic rocks form everywhere the summits of the Andes; they sometimes attain the thickness of twelve thousand feet, and they are elevated in the mountains of Cotopaxi and Chimborazo to heights exceeding twenty thousand feet above the level of the sea.

fig. 72.

SECTION OF THE UNITED STATES, FROM EAST TO WEST.



The upper division of the section commences on the right at the shore of the Atlantic, where the middle tertiary (miocene) are represented by the figure 1; the lower tertiary (eocene) by 2; and the upper secondary (cretaceous) by 3. A succession of beds of gneiss, mica-slate, and other primary rocks next occur (4); and farther west, the Alleghany mountains exhibit the transition rocks (Silurian) in various contorted folds, which become gradually flatter towards the west, where there is an extensive coal field (6). The coal measures rest upon old red sandstone, which rises through and separates the coal, which reappears in the lower division of the section on the right. The gneiss and mica-slate, accompanied by granite veins, recur at 8, and the transition rocks again protrude at 5. The Illinois coal field occupies the western part of the outcrop of the transition rocks, and at the extreme west is the rich coal field of the Mississippi.

In North America, the chain of the Rocky Mountains on the west exhibits the series of granite and other primary rocks, followed by transition beds, the old red sandstone, coal, and the overlying new red sandstone. In the more eastern and less elevated range of the Alleghanies, the lower transition rocks form the summits of the mountains; and on their flanks and in the valleys are extensive coal districts, which spread over areas of many thousand square miles. The coal of the Mississippi occurs in such thick beds, and lies so near the surface, that it is worked in open quarries. The coal is generally of the kind called anthracite, like that of South Wales, though excellent, blazing, bituminous coal is met with in some of the coal fields. There is a comparative scarcity of tertiary strata in North America, and the fossils differ materially from those found in corresponding beds in the Old World, though several of the genera and species are identical. The upper secondary strata are also deficient, and there is no chalk on the American Continent. California is situated on the western flanks of the Rocky Mountains; where the primary beds, and the gold-containing quartz dikes, are diversified by porphyry and volcanic rocks. The accompanying section of the country from the Atlantic to the sources of the Mississippi, a distance of 850 miles, from east to west, is taken from the "Manual of Geology," by Sir Charles Lyell, who has attentively examined the geological structure of the United States.

The geology of Australia has acquired great importance since the discovery of its stores of gold. The primary rocks, granite, porphyry, gneiss, mica-slate, and clay-slate, are well developed in mountain ranges that run in parallel directions from north-east to south-west. Tertiary beds occupy extensive areas on the flanks of the mountains, and in the low ground; but there is a comparative deficiency of secondary strata. The immediate neighbourhood of the "gold diggings" consists of schist diversified by quartz dikes, vertically bedded and fissured by deep creeks. Where the points of junction with minor creeks occur, bars of schist seem to accumulate fluviatile and more ancient drift, and it is there especially that the gold is accumulated. In some places the quartz is studded with nests of gold, very abundant, and easily detached by the blow of a hammer. Gold is found in Australia, over an area of 700 square miles, in the tract of the Macquarrie alone, and that is but a portion of the area where it may be deposited.

CHAPTER XVIII.

GEOLOGICAL THEORIES.

Agency of internal heat.—Fusion of the materials of the globe inferred from its shape and the variations in gravitating force.—Gravitation a probable source of internal heat.—Supposed action of water and heat in disintegrating rocks. Progressive development of the condition of the globe.—Extinction and creation of genera and species of animals.

The facts made known by geological researches necessarily induce speculation as to the causes that have produced such remarkable changes in the structure of the globe and in its inhabitants at different periods. We have, from time to time, considered the causes of the separate phenomena as they presented themselves to notice; but we have reserved for the conclusion of our description of geological arrangements, a view of the theories that are supposed to account most rationally for the general structure of the globe, and the disturbances by which it has been agitated.

The original theory of Werner, who attributed the formation of all strata entirely to the successive depositions of earthy matter from aqueous suspension, has been for some time exploded; and all geologists seem to admit the agency of internal heat, either as at present operating, or at least as having been active during the formation of the primary and transition rocks. Some division of opinion, indeed, exists respecting the cause of internal heat, it being attributed by some to chemical action arising from the combustion of the metallic bases of the earths and alkalies when they come in contact with water; but the more general opinion is, that the materials of the earth were originally in a state of fusion; that the crust of the globe became solidified by cooling; and that a great nucleus of heat still remains in the centre of the earth.

As the source of internal heat has not been ascertained, it is impossible to estimate its highest degree of intensity. So far as experimental investigations extend, the temperature of the earth increases one degree of Fahrenheit's thermometer every seventy feet of perpendicular descent; and, supposing it to continue to increase at the same ratio, at a depth of 50 miles the temperature would be sufficient to fuse the hardest rocks. According to the theory of the correlation of forces, which has recently been received with much favour by scientific men, gravitation, heat, chemical attraction, &c., are merely various modifications of some single force, and each one can produce the other. If this theory be applied to explain the cause of central heat, we may suppose the heat to be derived from the mere pressure of gravitation; and in that case it would become more and more intense, though in a diminishing ratio, towards the centre.

The oblate spheroidal shape of the globe also affords ground for other and important inferences respecting its condition, which may be brought within the range of mathematical calculation. The form of a sphere flattened at both ends and protruding in the middle, is that which it is known any mass of matter would assume if rotating on an axis, and its particles were free to move. It may be inferred, therefore, from the shape of the earth, that the materials which compose it were once in a fluid state; and, assuming the presence of internal heat, it may likewise be inferred, that the condition of fluidity was occasioned by fusion. Now it is evident, that the particles of a fluid rotating mass would adjust themselves so as to produce an equilibrium in all parts of the globe. For instance, if the globe were at rest, it would assume a perfectly globular form; and the attraction towards the centre at all points of the surface would be the same. But by the rotation on its axis, the action of what is termed "centrifugal force" would diminish the attraction of gravitation near the equator, where the velocity of rotation is greatest, and an additional quantity of fluid matter would be accumulated there to counterbalance the centrifugal action. This accumulation of matter near the equator—which, if the rotation of the earth on its axis were to cease, would considerably add to the weight of bodies as they approached that portion of the globe—would be only just sufficient to counterbalance the centrifugal tendency occasioned by the rotation; and a perfect equilibrium would be maintained, if the fluid state of the mass allowed the particles to adjust themselves. In the present state of the globe, however, this equilibrium is not maintained; for the attraction of gravitation diminishes as we approach the equator, notwithstanding the diameter of the earth at that point exceeds, by twenty miles, that at the poles. This fact has been determined by accurate observations on the vibrations of pendulums in different latitudes; the vibration becoming perceptibly slower nearer the equator. To produce such an effect as this, we must assume that after the surface of the molten mass had been cooled and consolidated, so that it could no longer alter its general form, there was deposited upon it a quantity of matter of less specific gravity than the internal mass. This covering of lighter materials, by extending the distance from the surface to the centre, would increase the velocity of rotation, and diminish the attraction of gravitation at the equator; and such disturbance of the equilibrium could not be adjusted after the crust of the globe had become consolidated.

The diminution of the gravitation of the earth at the equator, and the causes which would produce it, are in accordance with known facts, and with the circumstances that it may be presumed would necessarily attend the cooling of the globe from an incandescent state. The water which now covers so large a portion of the earth's surface, must then have been in a vaporous condition, and, mingled with the air, the atmosphere must have occupied much greater space than its present limits. The cooling of the molten mass would produce irregularities on the surface by contraction as great as, or greater than, those in the present mountains and valleys. The vapour would first condense on the highest and coolest parts, and the water on running down into the declivities would be again converted into steam. The succession of condensations and vaporizations would induce chemical action, which, combined with mechanical erosion from the running water, would disintegrate the surface, and occasion the deposition of the particles on the lower levels. In this manner we may conceive that, after a long succession of revolutions round the sun, the beds of primary rocks that rest immediately on granite might be formed. Nor need we limit the operations to a continued process of cooling; for various circumstances might have arisen to have caused the ejection of molten matter to the surface, and thus the processes of remelting and cooling might have been repeated for long durations of time. Neither is it necessary to imagine any great convulsion to have been requisite to produce such effects; for when we consider that our highest mountains bear no greater proportion to the mass of matter on the earth than a few grains of sand do to the body of a twelve-inch globe, and that the thickest stratum of rocks is but as a coating of dust on the same globe, it need not excite surprise that such superficial particles should be disturbed and broken through by internal movements in the melted materials of the earth. Among the causes that might occasion irregularities of surface in cooling, the attractive powers of the sun and moon should not be omitted, which, it may be assumed, produced tides in the whole molten mass of greater extent than in the comparatively shallow waters of the ocean.

Having laid the foregoing foundations for geological speculation, there will be little difficulty in conceiving the general plan by which the superstructure has been raised. With an admitted source of internal heat, to be applied whenever required, and being allowed a countless succession of years to effect the deposition of strata, geologists can explain most of the phenomena that present themselves, connected with the mere construction and arrangement of the materials of the earth;

and in general principles they are for the most part agreed. They agree in opinion, that the rocks which lie in succession upon one another were formed by the disintegration of the rocks on which they rest; occasionally diversified by the obtrusion of igneous rocks, which, in their turn, assisted by their disintegration in the formation of strata. They agree, that the deposition of the transition and secondary rocks was effected, for the most part, under water, and that the crust of the globe has, at several different periods, been raised above the level of the sea, which has again covered it; and they further agree, that these movements have been effected by subterranean agencies. But there are numerous points of minor importance respecting which geologists differ.

The theoretical question which now excites most attention, is, whether the changes on the surface of the earth have been produced by convulsive movements, succeeded by long periods of repose; or, whether they have been brought about by the gradual influence of causes that are constantly in operation.

The former is the older theory, and the one most generally adopted; the latter has, however, been making considerable progress by the zealous and able advocacy of Sir Charles Lyell. The enormous deposits at the mouths of great rivers, formed by the *débris* from inland mountains and high grounds; the known gradual subsidence of the land in some places, and its elevation in others; the drainage of extensive lakes, the beds of which exhibit freshwater deposits; the rents and fissures caused by earthquakes, and the immense tracts covered by eruptions from volcanoes within the range of history, are evidences adduced by Sir Charles Lyell, to prove that such causes would be adequate, if continued for an unlimited period, to produce changes equal to those that are observed to have taken place on the earth's crust in past geological time.

There is, however, so much general uniformity in the deposition of the lower rocks, and there are such marked changes in the characters of distinct formations in all parts of the world—especially in those that have taken place between the transition and the secondary, and between the secondary and the tertiary formations—that it is difficult to imagine they were not produced by some universal cause operating at the same time, and by some grand movements different from any that have been produced in historic time.

If we admit, therefore, that the operation of existing causes would be sufficient to produce most of the changes that have taken place during the tertiary periods, we can scarcely admit their sufficiency to produce such general upheavings of the land as occurred before the commencement of the coal series, and the subsequent subsidences under the level of the sea; nor, even in the most recent geological periods, can existing causes account for the sweeping away of immense masses of strata from the surface, and the deposition, alike on mountain and in valley, of vast blocks brought from far distant regions.

The conclusion at which we arrive, after consideration of the theory of progression, is, that whilst important changes on the earth's surface are continually taking place under the influence of existing causes, they are not of such a character as to have produced the complete alterations that have occurred in certain periods of former worlds; and that though there has been at all times of the progress of the globe to its present state, the active operation of existing agencies, there have been also successions of "paroxysms" which have effected greater disturbances in the condition of the globe than could have been effected by progressive action.

With regard to the creation of new species, that is one of the mysteries as yet beyond the bounds of human comprehension, and probably will for ever remain so.

Though the generally admitted progressive development of the condition of the globe is accompanied by a progressively increasing complexity of animal organization, there is not observable in the succession of animated beings any approach to transmutation from a lower to a higher form of life; and geological research, as well as physiological investigation, contradicts such an assumption. Whilst, therefore, there has been, and continues to be, a PROGRESSIVE DEVELOPMENT *of the condition of the earth,* occasioned by the decomposition of its elementary rocks; the PROGRESSIVE ORDER *of animal life,* which accompanied it, had no apparent antecedent cause; and, so far as human knowledge extends, the introduction of new forms of life, in advanced conditions of the globe, has been produced by the special agency of Creative Power.

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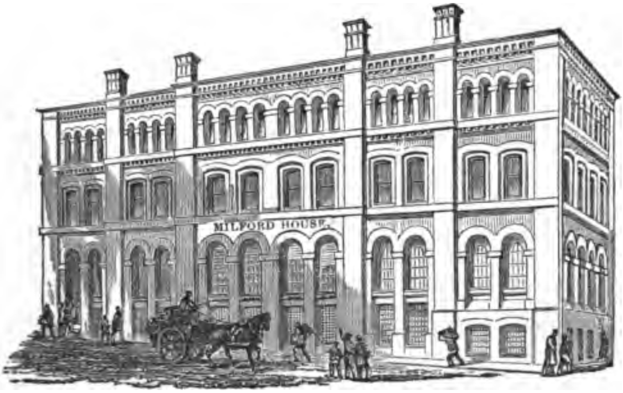

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